A.D. 1869, 3rd *May.* N° 1352.

SPECIFICATION

OF

CHARLES THIEME LIERNUR.

REMOVING AND UTILIZING SEWAGE.

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Removing and Utilizing Sewage.

LETTERS PATENT to Charles Thieme Liernur, of the Firm of Liernur, Krepp, and Company, American Engineers, Frankfort-on-the-Maine, in the Kingdom of Prussia, for the Invention of "IMPROVEMENTS IN THE DAILY INODOROUS REMOVAL AND AGRICULTURAL UTILISATION OF HUMAN EXCREMENTS, KNOWN AS LIERNUR'S PNEUMATIC SEWERAGE SYSTEM."

Sealed the 17th August 1869, and dated the 3rd May 1869.

PROVISIONAL SPECIFICATION left by the said Charles Thieme Liernur at the Office of the Commissioners of Patents, with his Petition, on the 3rd May 1869.

I, CHARLES THIEME LIERNUR, of the Firm of Liernur, Krepp, and Company, American Engineers, Frankfort-on-the-Maine, in the Kingdom of Prussia, do hereby declare the nature of the said Invention for "IMPROVEMENTS IN THE DAILY INODOROUS REMOVAL AND AGRICULTURAL UTILISATION OF HUMAN EXCREMENTS, KNOWN AS LIERNUR'S PNEUMATIC SEWERAGE SYSTEM," to be as follows:—

1. General Description.—The various improvements herein-after specified are mere parts of a system to render faecal matter useful

instead of noxious. These improvements all tend to this one purpose, referring all to one and the same Invention, for which Patents have been granted in nearly all civilized countries under the style and denomination of "Captain Liernur's Pneumatic Sewerage System."

2. Inseparability of these Improvements.—Although some of these improvements refer to the system of pipes used for removal of faecal matter out of houses, whilst others refer to the utensils serving for inodorous removal out of town, and for mixing the liquid manure with the soil, and to the particular division of the fields required in connection therewith, still all these improvements form only parts of a single system, as indicated in paragraph 1.

3. Distinction between this and all other Sewerage Systems.—All other sewerage systems labour under one common deficiency, namely, they all fulfil only in part the requirements of public health, agriculture, communal and national economy, and public morality. All these other systems do not go any farther than to remove the filth from one place where it is in the way to another place where it is likewise in the way, so that in the end nothing is obtained but annoying one part of the community with the faecal filth of another part, to the great detriment of public health.

4. Final Disposal of Faecal Matter.—This system, on the contrary, has this striking feature, that it takes care of faecal matter from the moment of its production through all intermediate stages until it is finally disposed of in the only proper place it belongs to, namely, the domain of agriculture; and all this is done in so short a time that excrements cannot ferment and thereby become dangerous to public health. From beginning to end all my arrangements tend consistently to this one useful purpose, in strict accordance with the laws of nature and the requirements of modern science. In one word, excrements are daily moved out of the privies into the open fields, and this has never been done by any other system.

5. This Sewerage and Agricultural System one Indivisable whole.—It is therefore impossible to consider the improvements herein-after described as so many distinct Inventions without interfering with the proper operation of the whole system, or even rendering it useless altogether.

6. Specification and Drawings.—In the following Specification of the various improvements alluded to it is supposed the leading features of this sewerage system as patented already (No. 898, A.D. 1866) are known

to the reader. In referring to the annexed Drawings the same letters always apply to the same objects.

I.—First Improvement.

7. Self-acting Valves of Lateral Pipes. (See Drawing, Fig. 3, Sheet II.) —This improvement refers to the manner of shutting off the lateral pipes from the main tube, which in the original Patent is effected by means of valves to be opened and shut each one by itself with a lever applied from the street. These sliding valves, which are very expensive and often of difficult access on account of snow or street mud, and besides consume much time and labour in their working, are now supplanted by the following simple self-acting arrangement.

8. Description of Self-acting Valves. (See Drawing, Figs. 3 and 1, Sheet I. and II.)—The lateral pipes (B) in joining the main tube (A) empty with a slight curve into a box (C), so that both pipes get into one line. At the end of the lateral pipe there is a valve (D) turning on a horizontal axle and kept closed by a weight (P). This valve is so arranged that it opens itself the moment a pressure arises inside heavier than the weight (P). All lateral pipes (see Fig. 1) opening into a main tube (A), which in its turn is connected with a reservoir (R), are provided with valves such as just described.

9. Main Turncock. (See Drawing, Fig. 3, Sheet II.)—Quite close to the reservoir (R) the main tube (A) is provided with a main turncock (H), which may be opened and shut by means of a lever applied from the street; and this main cock is, with the new improvement, the only part of the pneumatic pipe system requiring manual labour.

10. Formation of a Vacuum. (See Drawing, Fig. 3, Sheet II.)—When a vacuum has been made in reservoir (R), main cock (H) is suddenly opened, upon which the air contained in the main tube (A) will of course rush into the reservoir, generating thus a partial vacuum in the entire length of main tube (A). This occurs in so very short a time that the valves D of all the lateral pipes are only, after the formation of this partial vacuum, opened through the expansion of the air up to this moment shut up in all the lateral pipes.

11. Vis Inertiæ of the Valves. (See Drawing, Fig. 3, Sheet II.)—The explanation of this short delay is the opening of the valves is found in their vis inertiae, which allower the much lighter air in the main tube (A) to escape through the open turncock (H) into the airless reservoir (R),

leaving behind a partial vacuum quite sufficient for lifting up the valves (D).

12. Main Point of this Improvement. (See Drawing, Fig. 3, Sheet II.) —This making use of vis inertiae for the purpose of effecting an equality of vacuum along the whole length of the main tube of sufficient strength for removing faecal matter out of the lateral pipes that contain any, while those that contain none offer, through being equally shut, exactly the same resistance, is the main point of this improvement. The vis inertiae of bodies is, as is well known, in proportion to their weight. The lighter body (in the present instance the air in the main tube (A) moves sooner than the much heavier valves (D), both being exposed to the very same acting force, namely, atmospheric air. The valve weight (P) is made to weigh 12 kilograms, whilst the air in the interior of the main tube (A) weighs only 1 $\frac{3}{10}$ kilograms per cubic meter. This air must consequently rush into the reservoir (R) with so great a velocity that in the entire length of main tube (A) a partial vacuum of uniform strength is established before the vis inertiæ of a single valve (D) is overcome.

13. Proportional Capacity of Reservoir and Main Tube. (See Drawing, Fig. 3, Sheet II.)—In order to obtain the requisite pressure for opening the valves (D) the reservoir (R) is made of at least double the contents of main tube (A). If the latter contains, for instance, one cubic meter the reservoir must contain at least two cubic meters, and so on through all respective sizes which may be required.

14. Vacuum in Reservoir and Main Tube. (See Drawing, Fig. 3, Sheet II.)—If the air of the reservoir (R) is exhausted to $\frac{1}{4}$ atmosphere (which by means of my improved pneumatic locomobile is done in about 30 seconds) and the turncock (H) suddenly opened, then 1 cubic meter air contained in main tube (A) will rush into reservair (R) (which still holds $\frac{1}{4}$ of 2 cubic meters = $\frac{1}{2}$ cubic meter of air). Both reservoir and main tube will then contain together $1\frac{1}{2}$ cubic meters of air spread over a space of 3 cubic meters, and thus a partial vacuum of half an atmosphere will be established quite sufficient for the removal of faecal matter.

15. Pneumatic Pressure on the Valves. (See Drawing, Fig. 3, Sheet II.) – As the valves have a diameter of 0·125 meter (the same as the main and side tubes) their surface is 122 □ centimeters, exposed to an atmospheric pressure of 122 × $\frac{1}{2}$ kilograms = about 60 kilograms, whilst the weight (P) is only 12 kilograms. The pressure is therefore

five times stronger than what is required to raise the valves (D), which consequently open with great velocity and force the moment their vis inertiae is overcome.

16. Difference of Time in Forming the Vacuum in the various Parts of the Main Tube. (See Drawing, Fig. 3, Sheet II.)—The first and last valve (D) of main tube (A) will of course not open the very same moment, though very quickly one after the other, because the partial vacuum requires a minute fraction of time to spread itself to the further end of the main tube. For instance, if in main tube (A) the first valve (D) is 10 meters distant, and the last valve (D) is 100 meters distant from turncock (H), the vacuum will reach the first valve $\frac{1}{30}$ second, and the last valve $\frac{1}{10}$ second after the opening of the turncock.

17. Simultaneous Opening of all the Valves. (See Drawing, Fig. 3, Sheet II.)—To secure a simultaneous opening of all the valves their weight is reduced in proportion to their distance from the turncock (H), so that their vis inertiae may be overcome so much the sooner; as the vacuum requires more time to spread to each respective valve, given the distances mentioned in paragraph 16,—this reduction of weight must correspond to the difference of time between $\frac{1}{30}$ and $\frac{1}{10} = \frac{1}{15}$ second. Therefore the first valve must weigh 12 kilograms, the last only 10 kilograms, the intermediate valves in proportion. Hence in practice the rule is to reduce the weight of every valve 0·2 kilograms for every 10 meters distance from the turncock (H).

18. Exact Equalization of Distances and Weights not necessary.—Great exactness in this adjustment of weights is not at all required because the vacuum will anyhow reach every individual valve soon enough to expose it to an atmospheric pressure 5 or 6 times greater than the weight which keeps it closed. Even with a tolerably great difference in the resistance of the various valves all will open with equal velocity, as actual trials with glass tubes of $2\frac{1}{2}$ centimeters in diameter have conclusively proved. The explanation of this fact is the same as that of the effect of an overcharged powder mine. The explosion does not follow exclusively the direction of the least resistance, but acts violently in all directions, because the excessive velocity leaves no time for an equilization of resistance.

19. Increased Velocity in the Opening of the Valves. (See Drawing, Fig. 3, Sheet II.)—The vis inertiae valves (D) are so constructed that their weight diminishes while opening. The weight (P) has therefore

its point of gravity in the same horizontal plane as the axle of the valve. So soon as the latter turns the weight (P) gets lighter in proportion as the cosines of the ascending angle become shorter. The valve would be in perfect equilibrium if the weight (P) stood vertical over the axle, which however is prevented by the construction of the valve, so that the same is always compelled to fall back and shut itself the moment the violent rush of air out of the side pipe into the main tube ceases.

20. Slackened Motion of the Valves in Falling Down. (See Drawing, Fig. 3, Sheet II.)—To prevent a violent slamming of the valves in falling down the upper and lower parts of the same are alike, forming a kind of fan which strikes the air, and thereby moderates the velocity of the fall. This fan, on the other hand, is no hindrance in the quick opening of the valve, because this opening occurs in a partial vacuum offering no markable resistance to the fan.

21. Lid of the Valve Box. (See Drawing, Fig. 3, Sheet II.)—The upper part of the valve box (C) is hermetically closed by a double lid, the lower part of which shuts out the air, whilst the upper part on the level with the street pavement merely serves to protect the lower one from injury.

22. Hermetic Tightness all over the Subterranean Pipe System not absolutely necessary.—It is not absolutely necessary that all parts of the subterranean pipe system should close hermetically, it is quite sufficient if all parts are only water-tight. The vacuum forming in about two seconds at the most, this time is by far too short for sufficient air to penetrate through any small fissures which may exist here or there so as to interfere in a sensible degree with the pneumatic process. Besides any small fissure or crack will soon fill itself by particles of earth or mud being sucked in out of the adjoining soil.

23. Hermetic Tightness required only in the Reservoir and Turncock. (See Drawing, Fig. 3, Sheet II.)—The only parts of the subterranean system which must be perfectly air-tight and remain so are the following:—*a*, the reservoir (R); *b*, the turncock (H); *c*, the small piece of pipe connecting both. These parts however are comparatively so small that to make and keep them air-tight offers no technical difficulty at all.

24. Reliability of the Turncock. (See Drawing, Fig. 3, Sheet II.)—The turncock (H) is so constructed that if any derangement does occur it may be examined and repaired in a very short time; for this purpose

the turncock is simply lifted out of its box, and the impediment being removed, is put back again. Nothing is liable to be broken thereby. The box is closed by a double lid, as described in paragraph 21.

25. Fall of the Main Tube.—The main tube receives a fall of 1 in 150 at the least, and more if practicable, so that the faecal matters driven into it out of the lateral tubes (as long as they have not yet reached the reservoir) can collect through gravity in the lowest part of the main tube, whence a new pneumatic shock forces them into the reservoir. This reservoir is therefore located always at the lowest point of the soil upon which the group of houses connected with it stands.

26. Fall of the Lateral Pipes.—The lateral pipes receive a fall of at least 1 in 20 towards the main tube, and more if the levels of the ground permit. The entire network of pipes is thus provided with so strong a fall that the faecal matter moves downward by its own gravity to the lowest part of the pipes, there to await the repeated pneumatic shocks, which force them first into the main tube, and thence further on into the reservoir.

27. Breaks in the Fall of Long Lateral Pipes. (See Drawing, Fig. 2, Sheet I.)—To prevent that a long lateral pipe, by receiving a fall of 1 in 20, does not get too deep into the ground, it is from distance to distance, bent upwards again, as explained by Fig. 2, in Drawing. A is the diameter of a main tube; B, the lateral pipe connecting this main tube with the house pipe (F), which serves to collect the faecal matter out of all the privies in the house. The breaks in the fall occur at distances of ten meters from each other, the fall being $\frac{1}{2}$ meter in 10, or 1 meter in 20 on the whole. The upward bends are formed by pieces of pipes bent in a radius of 1 meter.

28. Pneumatic Evacuation Process with the Improved Vis Inertia Valves. (See Drawing, Fig. 3, Sheet II.) — After the reservoir (R) has been evacuated by the locomobile air pump the turncock (H) is suddenly opened, allowing the air contained in the main tube (A) to rush into the reservoir, leaving a partial vacuum behind. The air contained in the lateral pipe (B) expands, and thereby lifts up valve (D), this confined air exercising an initial pressure of at least 1 atmosphere. This pressure of course diminishes after the first moment, but the weight of the valve diminishing likewise (see paragraph 19) the valve will open entirely with great velocity. The escape and consequent rarefaction of the air in the lateral pipe (B) causes of course the faecal matter collected in the syphon K to move towards the main tube,

a movement which occurs simultaneously in all lateral pipes. The consequence is that a great deal of air enters out of the lateral pipes into the main tube and reservoir, re-establishing quickly the atmospheric equilibrium, and causing all the valves (D) to fall down and close themselves while the faecal matter not yet driven into the reservoir settles down by gravitation into the lowest part of the main tube. All this happens in about 30 seconds from the first opening of the turncock H. As soon as the vacuum meter of the pneumatic locomobile indicates this state of things the engine driver shuts turncock (H) and keeps it closed until the air pump has re-established the vacuum in the reservoir, which is done again in about 30 seconds; then the turncock is opened again and a new atmospheric shock drives the faecal matter collected in the main tube right into the reservoir. This simple proceeding is repeated as many times as there are breaks in the longest lateral pipe. The whole pneumatic evacuation of a great number of privies all connected with one reservoir is therefore effected by simply opening and shutting several times the turncock (H), allowing a pause of about ½ minute between each opening, and subsequently shutting until all faecal matter by repeated atmospheric shocks has finally been driven into the reservoir (R), the pneumatic locomobile keeping constantly in motion all the while. The reservoir in its turn is then emptied by pneumatic pressure into an air-tight waggon cylinder, as has been described in the original Patent.

29. Empty Privies of Uninhabited Houses Cause no Disturbance to the Pneumatic Process.—Privies happening to be empty do not prevent in any manner whatever the pneumatic evacuation of the other privies of a group of houses, because each individual lateral pipe has a valve of its own remaining closed by its weight until the vis inertiae of the same is overcome. The internal initial pressure on all the valves is alike, whether this results from atmospheric pressure direct through empty privies or from the expansion of confined air within the lateral pipes, and therefore all valves open simultaneously every time a partial vacuum is made within the main pipe independent of the privies containing any thing or not. If a valve is once opened and the privy is empty air alone streams in the lateral pipe, if the privy contains faecal matter this is carried along with the atmospheric stream, which must be produced when part of the confined air of the lateral pipe escapes in the main tube; even if all the privies connecting with a main tube were empty the valves of this lateral pipe would open and shut themselves with the same regularity and simultaneousness as when some

were full and others empty. There is no time for re-establishing the equilibrium of resistances.

30. The Reservoir an Accumulator of Motive Power and Collector of Faecal Matter.—The reservoir answers a double purpose. When the turncock is closed it accumulates the motive power generated during half a minute's work of the locomobile air pump, and expends this with a shock on all the valves when the turncock is opened; after this it collects the faecal matter which this shock has driven out of the entire network of pipes. By transmitting this stored up motive power in such atmospheric shocks to the vis inertia valves an effect is obtained far more powerful and decisive than a direct sucking of the air pump could produce.

31. Advantages of the Improved Vis Inertia Valves System. (See Drawing, Fig. 1, Sheet I.)—In addition to the various advantages alluded to in the preceding Specification there are two others to be explained by Drawing, Fig. 1, Sheet I), representing part of a town with a network of pneumatic pipes and reservoirs.

First Advantage.—A main tube may be put down in a street with valves for the adjacent houses without the necessity of all lateral pipes being laid at the same time. If only one lateral pipe is ready for the reception of faecal matter the main tube may begin its work which of course greatly facilitates the gradual introduction of the pneumatic system into a town, as the convenience of individual householders may be consulted.

Second Advantage.—Should one or the other privy or its lateral pipe get choked through some object being negligently thrown in which does not belong there, all valves are fastened except that with which the choked privy communicates, and thus the whole power stored up in the reservoir is concentrated on a given point. An alternate opening and shutting of the turncock produces by keeping the air pump constantly at work repeated shocks of nearly a whole atmosphere's power, which of course will effectually remove any obstruction in the privy or pipe in a very short time. The lower opening of the privy funnel is purposely made narrower than the lateral and main tubes, consequently anything passing at all through the narrow outlet of the privy funnel must of course also pass through the lateral pipe and main tube (which are wider than the said outlet) into the reservoir. The fastening of the valves above alluded to is effected by opening the valve box lid (see paragraph 21) and driving in a wooden wedge behind the axle of the valve.

Second Improvement,

Referring to new privy arrangements.

32. Pneumatic Privies, 1st Class. (See Drawing, Fig. 4, Sheet III.)—These new privies are so constructed that they may be emptied and cleaned through atmospheric blasts; faecal matter disappears under them immediately after production, the same as in waterclosets. The vertical pipe (F) receives the excrement dropping down from the various floors of the house. The funnel (T) is closed by a valve (D) provided with a counterweight (P) of 4 kilograms. This valve opens the moment a partial vacuum occurs in the vertical pipe through the evacuation process described in paragraph 28. The wider this valve opens the lighter the weight gets (see paragraph 19). The upper part of the funnel is double, and the space between both parts ($\frac{1}{2}$ centimeter wide) is connected with a ventilation pipe (E) reaching up to outside the roof of the house. In daytime this ventilation pipe carries off the exhalations of the funnel sides, whilst at night this same pipe admits the stream of atmosphere required for the evacuation (see paragraph 28). The friction due to this powerful atmospheric current keeps the funnel clean. Valve (D) likewise opens entirely and thus gets out of the way of falling matter as often as a person sits down upon the privy, so that no excreta can ever adhere to it. The front part of the sitting board turns upon pin (O), lowers itself 2 inches and presses upon the rod (V), which by its knobs (J) and the lever (X) opens valve (D). As soon as the person rises the sitting board rises likewise slowly through the weight (Z) and valve (D) shuts itself by its own gravitation. The sitting board as well as the upper part of the funnel (T) may at any time be taken off if cleansing should be required. All moveable parts are accessible so easily that any repairs can be effected with very little trouble.

33. Pneumatic Privies, 2nd Class. (See Drawing, Fig. 5, Sheet III.)—Second class privies are much cheaper and more simple in their construction, which is as follows:—Valve (D) is kept closed by a weight (P) in a perpendicular line so that no matter can adhere to it. The lower part of the funnel forms a hydraulic trap of so small a capacity that each new contribution of faecal matter forces those already there into the vertical pipe. Ventilation pipe (E) carries off the exhalations during daytime and admits at night the atmospheric current for pneumatic evacuation.

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34. Hydraulic Trap of the Vertical Pipe. (See Drawing, Figs. 6 and 2, Sheets III. and I.)—The vertical pipe of both classes of privies is closed by a hydraulic trap calculated to contain the daily excretae of 6 persons, say about 6 litres, any surplus over that quantity generally only the liquid part runs off into the lateral pipe (see Fig. 2). The matter collecting in this trap, and mostly composed of solids, is carried off into the lateral pipe by a pneumatic shock the moment a partial vacuum is formed, as described in paragraph 28.

35. Privies for the Poorer Classes.—Privies for the poorer classes, with whom cheapness is a main object, open into a vertical pipe with oblique funnels for the various floors of the house. This vertical pipe reaches above the roof for ventilation whilst the lower end is provided with a hydraulic trap, as described in paragraph 34.

36. Pneumatic Privies in Groups for Large Establishments. (See Drawing, Figs. 7 and 8, Sheets IV. and V.)—For schools, factories, military barracks, and other large establishments privies are arranged in groups, as shown in Drawing, Figs. 7 and 8, Sheets IV. and V.; Fig. 7 shows the privies placed in a straight line; Fig. 8 on the contrary privies grouped in a circle, pissoirs being included in both cases. Each single privy consists in an iron funnel glazed inside with a small hydraulic trap below calculated to contain the daily evacuation of 2 to 3 persons. Equilibrium pipe (G) connects all privies, so that the same level of faecal matter is maintained in all. As the quantity contained in each is therefore the same the vis inertiae of the respective masses must also be alike in all the privies, and consequently a partial vacuum formed in the collecting pipe (L) or in the collecting funnel (M) will simultaneously evacuate all these privies. As in large establishments, such as barracks or schools, great quantities of faecal matter are daily to be removed the pipe connecting with them is made a main tube (A) and provided with a turncock so that the pneumatic power may be so much more concentrated.

37. Pneumatic Privies grouped in different Floors of a large Building. (See Drawing, Figs. 7 and 8, Sheets IV. and V.)—If in a large establishment the groups of privies are situated one above the other on different floors there is a vis inertia valve (D), either at the end of the collecting tubes (L, Fig. 7) or at the bottom of the collecting funnels (M, Fig. 8), this valve being in both cases kept closed by a weight (P.) The vertical pipe is closed air-tight at the top, so that a

partial vacuum may be formed in its entire length before the vis inertia valves open themselves. The moment the valves open the evacuation takes place simultaneously in all the privies, the entire faecal mass plunges into the airless vertical pipe, and is driven like a piston through the main tube into the reservoir.

Third Improvement,

Referring to an apparatus which can be put at will "in gear" for measuring the quantity of faecal matter freed by pneumatic pressure out of the subterranean reservoir into a waggon cylinder to indicate whether the latter is sufficiently filled, or whether there is still room for the contents of another reservoir, and which can be put "out of gear" when the waggon is driven away.

38. Two Domes on the Top of the Waggon Cylinder. (See Drawing, Fig. 9, Sheet VI.)—The atmosphere presses into the iron air-tight waggon cylinder (N) all faecal matter out of the subterranean reservoir the moment turncock (Q) is opened. This waggon cylinder is provided with two domes (U, U,) each having a pipe with a turncock leading to the hind part of the waggon cylinder. One of these pipes is coupled by means of a flexible hose with the subterranean reservoir, the other with the locomobile air pump, which through this double connection can establish a vacuum simultaneously in the waggon cylinder and subterranean reservoir. At the same time there is no danger of any spray or drops of faecal matter being sucked into the air pump, such drops being invariably precipitated on their way from one dome to the other.

39. Description of the Measuring Apparatus. (See Drawing, Fig. 9, Sheet VI.)—The hindmost dome of the waggon cylinder contains the measuring apparatus, consisting in a hollow float (*a*), which rises and descends along rod (*b*), and can be lowered by means of two light chains (*c*) and the pulleys (*d*); rod (*b*) does not reach quite down to the bottom of the cylinder, so that no rags, etc. can remain hanging to it when the waggon is emptied. The axle of the pulleys (*d*) passes through an air-tight stuffing box to outside the dome, and carries there a spiral spring, which unwinds the chains when the float falls, and winds them up when it rises again, being so adjusted as to maintain said chains (*c*) always in equilibrium. The axle is further provided with a small cog wheel acting upon a larger one which carries the indicator (*e*). The proportion between these two cog wheels is such that a whole

revolution of the indicator (*e*) corresponds to a whole rise of the float (*a*). If the indicator shows zero then the cylinder is quite empty, and if the float rises the indicator turns around until it points 1 degree before zero; then the cylinder is quite full. At this point the dial plate is provided with a catch for arresting the indicator, thus keeping the float suspended at its greatest height. This prevents the latter from dancing up and down with the liquid matter whilst the waggon is in motion, and thus guards the whole of this guaging machinery against the wear due to such incessant and excessive action. The indicator is provided with a knob, so that it can be used as a crank for winding the float easily up to the point where it can be stopped.

Fourth Improvement,

Referring to the apparatus for filling barrels out of the waggon cylinders in a perfectly inodorous manner.

40. Decanting Station and Storehouse for Dung Barrels. (See Drawing, Fig. 10, Sheet VI.)—In the hinder part of the building is a sunk recess (I), to which lead two cramps or inclined planes (W), one for rolling down the empty barrels, the other (which is of an easier gradient) for rolling up the barrels when filled with manure. The centre part of the floor is fenced off to serve for storage room for the barrels, both empty and filled. Opposite the middle of the recess (I) is the place to which the cylinder waggons are to be backed up for decanting their contents into barrels.

41. Decanting Apparatus. (See Drawing, Fig. 11, Sheet VII.)—The dung hose (*f*) is coupled to a turncock (*m*) fastened into the floor, beneath which hangs a large basket (*g*). A dung measure (*h*) is suspended below this on one end of a large balance (*l*); the other end of this balance holds a scale with a number of weights. The dung measure (*h*) is also provided with a turncock (*n*), and this, like the upper cock, has a long handle for working it with ease. The upper turncock (*m*) is connected through a leather hose (*o*) with the dung measure (*h*), so that this can freely follow up and down the motion of the balance (*l*). The leather hose (*o*) is fitted with a number of iron rings so as to keep its folds neatly. The lower turncock (*n*) just fits into the bung hole, which is alike for all classes of barrels. The balance scale (*p*) is now loaded with a number of weights corresponding to the exact contents of the dung barrel about to be filled.

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42. Guaging and Filling of the Dung Barrels. (See Drawing, Fig. 11, Sheet VII.)—To suit the individual requirements of farmers various classes of barrels are kept, containing respectively 3, 4, 5, 6, or even more, hundredweights of liquid dung. All barrels are gauged and marked according to their contents in weight. The filling operation is then as follows:—After the scale (*p*) has been loaded with the weights corresponding to the gauge of the barrel about to be filled dung hose (*f*) of the waggon cylinder is coupled to turncock (*m*) in the floor. The turncock of the waggon and the turncock (*m*) are then opened, thus causing the liquid dung to rise into the basket (*g*), which retains all rags, bones, etc., etc., so that no solid substances whatever reach the dung measure (*h*). As soon as the latter is filled with the quantity of dung corresponding to the number of weights lying in the scale (*p*) the balance will assume a horizontal position, upon which the operator shuts cocks (*m*), presses the dung measure still further down until the lower cock (*n*) fits into the bung hole of the barrel and fastens the dung measure in this position by means of a hook fixed to a wall of the building. After this the lower cock (*n*) is opened, the barrel will then be exactly full without spilling, because its contents have been determined beforehand by weights corresponding to its proper gauge.

44. Escape of Air out of the Barrel during the Filling. (See Drawing, Fig. 12, Sheet VII.)—The lower turncock (*n*) has a ventilation hole (*s*), which communicates through a thin caoutchouc hose with ventilation pipe (*t*). A similar hose (*u*) connects a ventilation hole in the lid of the dung measure (*h*) with the same pipe (*t*), which carries off all gases escaping during the filling operation above the roof of the building, where, if necessary, these gases may pass through the grate of a small fire. A caoutchouc ring is laid between the turncock (*u*) and the barrel to prevent all escape of gas there.

45. Bung Hole of the Dung Barrels. (See Drawing, Figs. 12 and 13, Sheet VII.)—The bung hole of the barrels is provided with a cast-iron ring in which a bung with a small safety valve (R) can be screwed in. This valve opens itself whenever an accumulation of gases takes place strong enough to burst the barrel unless this outlet were provided.

Fifth Improvement,

Referring to the Apparatus for Ploughing the Fresh Human Manure direct into the Soil.

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46. Improved Manuring Plough. (See Drawing, Fig. 14, Sheet VIII.)—A two-wheeled cart carries on the prolongation of its shaft two blocks (1), in which a dung barrel can be laid right across the track of the car. Behind the cart hangs a wooden frame having in its lower beam a number of strong iron hooks set in a row about three inches apart, on each of which a light plough may be alternately hung just as may be needful for drawing a furrow at the exact place where it is required. This enables the labourer to spread the liquid dung in parallel furrows or a track of at least one meter wide without changing the direction of the cart.

47. Loading and Fastening the Dung Barrel. (See Drawing, Fig. 14, Sheet VIII.)—In front of the cart there is a windlass (3) worked by means of a crank (4), while behind two skids (S) are hung leading up to the rear end of the cart. A rope slung around the dung barrel is hooked with one end to the rear part of the cart, whilst the other end is fastened to the drum of the windlass. By turning the crank (4) the barrel is wound up until it lies across the blocks (1). The barrel is then turned round until the bung hole lies upward, the iron bung is screwed out, a cock (5) inserted in its place is connected with a 2-inch dung hose (W). The barrel is then turned round again until the cock is below. The rope is tightened with the windlass and fastened in the right position by means of a small pawl working on a ratchet of the windlass. To facilitate turning the barrel backwards and forwards small rollers are set into the blocks (1). The skids (S) which served for hoisting up the barrel are during the ploughing of course laid aside.

48. Dung Nozzle and Rake. (See Drawing, Fig. 14, Sheet VIII.)—The dung hose (W) terminates in a nozzle (6) and reaches to behind the ploughshare, where it squirts the liquid manure into the furrow just drawn. A rake (8) behind the ploughshare covers the dung with earth immediately after, so that all evaporation of ammonia is prevented.

49. Regulating the Dung Stream and Closing the Dung Hose. (See Drawing, Fig. 15, Sheet VIII.)—On the lower beam of the wooden frame there is a regulator consisting of an iron shoe (y) on which the dung hose rests; this shoe can be shifted to the right or the left on the beam (2) just as the position of the plough requires it. The shoe (y) has two lugs bearing a lever (x), the lower part of which is broad and flat. A spring (z) presses this part of the lever down upon the dung hose, flattening and thereby closing it the moment the upper part of the

lever is set free by slackening a cord which the labourer holds in his hand whilst managing the plough. On the other hand a more or less strong pull at this cord opens the hose more or less and thus regulates the flow of the dung.

50. Manipulation of the Manuring Plough. (See Drawing, Fig. 14, Sheet VIII.)—Whilst a horse pulls the cart the laborer draws a furrow with the plough hooked on behind, pulls the cord, and thereby allows the liquid manure to be injected into the soil, while the rake closes the furrow immediately after. If a stone or root obstructs the track the laborer slackens the cord, thereby closing the dung hose entirely, and unhooks or turns the light plough (paragraph 46); he can then remove or avoid the obstacle.

51. Division of the Fields into Planting Beds and Manuring Stripes.—The fields are divided into alternate planting beds and manuring stripes, the latter being just wide enough for one or two horses to pull through the manuring plough just described. The planting beds are about double that width. The following year the new manuring stripes are laid just in the middle of the old planting beds, in other words, the alternate position of both is just reversed, so that those parts of the field which have been manured the preceding year are now used as planting beds.

52. Manuring Stripes in Winter Time.—In winter time the liquid manure is either ploughed in so as to fall on top of the ground, and then covered with snow instead of with earth, or poured out into furrows drawn beforehand ere a hard frost set in. In both cases fermentation cannot take place, and escape of ammonia and all bad stench is prevented by the low temperature. When a thaw sets in the manure speedily percolates into the soil with the snow water, or if necessary can be finally covered up with earth by a fresh ploughing in.

53. Advantages of this Dung Stripe System.—The advantages of this new agricultural system may be shortly summed up as follows:—1stly, there is all the year round a place for storing up fresh faecal matter as a fertilizer in the field itself without losing any organic ingredients, so that agriculture is greatly benefited, while at the same time the excreta are finally disposed of, and need no further care or treatment. 2ndly, all expenditure for manufacturing poudrette or analogous matter being avoided, the farmer gets the manure very cheap, and in a highly concentrated form. A far greater quantity of

atmospheric nourishment is procured both to the growing crops and the soil itself by the air passing through the manuring stripes and entering into the soil through the furrow repeatedly drawn at all seasons of the year. The dung stripes besides give easy access to all parts of the fields, which can thus so much the better be kept clean of weeds.

54. General Summary of my Improvements.

I. Improved Vis Inertia Valves. (See paragraphs 7 to 31, Drawing, Figs. 1 to 3, Sheets I. and II.)—A new mode of closing the lateral pipes of a pneumatic sewerage system by certain self-acting valves, termed by me vis inertiae valves, which are kept closed by a weight so calculated that its vis inertia requires more time to be overcome than the air confined in the main tube requires time to rush into a reservoir out of which the air has been exhausted, causing in the main tube a partial vacuum to be established along its entire length before a single valve is opened, and strong enough to overcome the vis inertia of said valves and to open them, so as to set thereby faecal matters in motion, which may be contained in all, or several, or one privy.

II. Improved Pneumatic Privies. (See paragraphs 32 to 37, Drawing, Figs. 6 to 8, Sheets III., IV., and V.)—A new construction of privies, the funnels of which are provided with self-acting vis inertia valves or self-acting vis inertia syphons, in such a manner that such privies are emptied pneumatically when the said valves or syphons open themselves after and in consequence of a partial vacuum being established along the whole length of the vertical pipe in which they discharge.

III. Measuring Apparatus for Waggon Cylinders. (See paragraphs 38 and 39, Drawing, Fig. 9, Sheet VI.)—A measuring apparatus set into a hermetically closed waggon cylinder, and consisting in a float which indicates the contents of the cylinder by rising and falling, thereby setting in motion a hand on a dial, which hand serves also to wind up the float, and to keep it suspended at its greatest height whilst the waggon moves along, so as to prevent the guaging machinery from being injured or worn out by the dancing up and down of the liquid.

IV. Inodorous Decanting Apparatus for Dung Barrels. See paragraphs 40 to 45, Drawing, Figs. 10 to 13, Sheets VI. and VII.)—An apparatus for decanting inodorously the contents of waggon cylinders into air-tight dung barrels. This apparatus consists mainly in an air-tight dung measure hung up at one end of a balance, while the other

end carries a number of weights laid into a scale, which corresponds to the gauge of the barrel to be filled, and the descent of the dung measure indicating the exact moment when the operator has to close the upper or inlet cock, whilst the loaded scale is secured against too quick a descent by a perforated piston moving in a subterranean cylinder filled with water.

V. Ploughing and Manuring Apparatus. (See paragraphs 46 to 53, Drawing, Figs. 14 and 15, Sheet VIII.)—An apparatus for simultaneously ploughing, manuring, and closing the furrows, with the following four peculiarities:—1, a furrow may be drawn and manured at any point over the whole width of the track without the cart leaving it; 2, the plough may be taken off from the cart at a moment's notice, for drawing a new furrow, avoiding stones or roots, or using the cart for some other purpose; 3, the same windlass which hoists the barrel upon the cart fastens it there; 4, the flow of the manure is regulated by a spring, which presses upon the dung hose or closes it altogether, according to the desire of the operator, and by his merely slackening a cord which he holds in his hand, and which lifts that spring or lets it go.

SPECIFICATION in pursuance of the conditions of the Letters Patent, filed by the said Charles Thieme Liernur in the Great Seal Patent Office on the 25th October 1869.

TO ALL TO WHOM THESE PRESENTS SHALL COME, I, Charles Thieme Liernur, of the Firm of Liernur, Krepp, and Company, American Engineers, Frankfort-on-the-Maine, in the Kingdom of Prussia, send greeting.

WHEREAS Her most Excellent Majesty Queen Victoria, by Her Letters Patent, bearing date the Third day of May, in the year of our Lord One thousand eight hundred and sixty-nine, in the thirty-second year of Her reign, did, for Herself, Her heirs and successors, give and grant unto me, the said Charles Thieme Liernur, Her special licence that I, the said Charles Thieme Liernur, my executors, administrators, and assigns, or such others as I, the said Charles Thieme Liernur, my executors, administrators, and assigns, should at any time agree with, and no others, from time to time and at all times thereafter during the term

therein expressed, should and lawfully might make, use, exercise, and vend, within the United Kingdom of Great Britain and Ireland, the Channel Islands, and Isle of Man, an Invention for "IMPROVEMENTS IN THE DAILY INODOROUS REMOVAL AND AGRICULTURAL UTILIZATION OF HUMAN EXCREMENTS KNOWN AS LIERNUR'S PNEUMATIC SEWERAGE SYSTEM," upon the condition (amongst others) that I, the said Charles Thieme Liernur, my executors or administrators, by an instrument in writing under my, or their, or one of their hands and seals, should particularly describe and ascertain the nature of the said Invention, and in what manner the same was to be performed, and cause the same to be filed in the Great Seal Patent Office within six calendar months next and immediately after the date of the said Letters Patent.

NOW KNOW YE, that I, the said Charles Thieme Liernur, do hereby declare the nature of my said Invention, and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

1. General Description.—The various improvements herein-after specified are mere parts of a system to render faecal matter useful instead of noxious. These improvements all tend to this one purpose, referring all to one and the same Invention, for which Patents have been granted in nearly all civilized countries under the style and denomination of Captain Liernur's Pneumatic Sewerage system.

2. Inseparability of these Improvements.—Although some of these improvements refer to the system of pipes used for removal of faecal matter out of houses whilst others refer to the utensils serving for inodorous removal out of town, and for mixing the liquid manure with the soil, and to the particular division of the fields required in connection therewith, still all these improvements form only parts of a single system, as indicated in paragraph 1.

3. Distinction between this and all other Sewerage Systems.—All other sewerage systems labour under one common deficiency, namely, they all fulfil only in part the requirements of public health, agriculture, communal and national economy, and public morality. All these other systems do not go any farther than to remove the filth from one place where it is in the way to another place where it is likewise in the way, so that in the end nothing is obtained but annoying one part of the community with the faecal filth of another part to the great detriment of public health.

4. Final Disposal of Faecal Matter.—This system, on the contrary, has this striking feature that it takes care of faecal matter from the moment of its production through all intermediate stages until it is finally disposed of in the only proper place it belongs to, namely, the domain of agriculture, and all this is done in so short a time that excrements cannot ferment and thereby become dangerous to public health. From beginning to end all my arrangements tend consistently to this one useful purpose, in strict accordance with the laws of nature and the requirements of modern science. In short, excrements are daily removed out of the privies into the open fields, and this has never been done by any other system.

5. This Sewerage and Agricultural System one Indivisable Whole.—It is therefore impossible to consider the improvements herein-after described as so many distinct Inventions without interfering with the proper operation of the whole system, or even rendering it useless altogether.

6. Specification and Drawings.—In the following Specification of the various improvements alluded to it is supposed that the leading features of this sewerage system as patented already (No. 898, A.D. 1866) are known to the reader. In referring to the annexed Drawings the same letters always apply to the same objects.

I.—First Improvement.

7. Self-acting Valves of Lateral Pipes. See Drawing, Fig. 3, Sheet I. —This improvement refers to the manner of shutting off the lateral pipes from the main tube, which in the original Patent is effected by means of valves to be opened and shut each one by itself with a lever applied from the street. These sliding valves, which are very expensive and often of difficult access on account of snow or street mud, and besides consume much time and labour in their working, are now supplanted by the following simple self-acting arrangement.

8. Description of Self-acting Valves. See Drawing, Figures 3 and 1, Sheet I.—The lateral pipes (B) in joining the main tube (A) empty into a box (C), with a slight curve so that both pipes get into one line. At the end of the lateral pipe there is a valve (D) turning on a horizontal axle, and kept closed by a weight (P). This valve is so arranged that it opens itself the moment a pressure arises inside heavier than the weight (P.) All lateral pipes (see Figure I.) opening into a main tube (A),

(which in its turn is connected with a reservoir (R)), are provided with valves such as just described.

9. Main Turncock. See Drawing, Figure 3, Sheet I.—Quite close to the reservoir (R) the main tube (A) is provided with a main turncock (H), which may be opened and shut by means of a lever applied from the street, and this main cock is with the new improvement the only part of the pneumatic pipe system requiring manual labour.

10. Formation of a Vacuum. See Drawing, Figure 3, Sheet I.—When a vacuum has been made in reservoir (R) main cock (H) is suddenly opened, upon which the air contained in the main tube (A) will of course rush into the reservoir, generating thus a partial vacuum in the entire length of main tube (A). This occurs in so very short a time that the valves (D) of all the lateral pipes are only, after the formation of this partial vacuum, opened through the expansion of the air up to this moment shut up in all the lateral pipes.

11. Vis Inertiae of the Valves. See Drawing, Figure 3, Sheet I.—The explanation of this short delay in the opening of the valves is found in their vis inertiae, which allows the much lighter air in the main tube (A) to escape through the open turncock (H) into the airless reservoir (R), leaving behind a partial vacuum quite sufficient for lifting up the valves D.

12. Main Point of this Improvement. See Drawing, Fig. 3, Sheet I. —This making use of vis inertiae for the purpose of effecting an equality of vacuum along the whole length of the main tube of sufficient strength for removing faecal matter out of the lateral pipes that contain any, while those that contain none offer, through being equally shut, exactly the same resistance, is the main point of this improvement. The vis-inertiae of bodies is, as is well known, in proportion to their weight. The lighter body (in the present instance the air in the main tube A) moves sooner than the much heavier valves (D), both being exposed to the very same acting force, namely, atmospheric air. The valve weight (P) is made to weigh 12 kilograms, whilst the air in the interior of the main tube A weighs only $1\frac{3}{10}$ kilograms per cubic meter. This air must consequently rush into the reservoir (R) with so great a velocity that in the entire length of main tube (A) a partial vacuum of uniform strength is established before the vis inertiae of a single valve (D) is overcome.

13. Proportional Capacity of Reservoir and Main Tube. See Drawing, Figure 3, Sheet I.—In order to obtain the requisite pressure for opening

the valves (D) the reservoir (R) is made of at least double the contents of main tube (A). If the latter contains, for instance, 1 cubic meter the reservoir must contain at least 2 cubic meters, and so on through all respective sizes which may be required.

14. Vacuum in Reservoir and Main Tube. See Drawing, Fig. 3, Sheet I.—If the air of the reservoir (R) is exhausted to $\frac{1}{4}$ atmosphere (which by means of my improved pneumatic locomobile is done in about 30 seconds), and the turncock (H) suddenly opened, then 1 cubic meter air contained in main tube (A) will rush into reservoir (R) (which still holds $\frac{1}{4}$ of 2 cubic meters $= \frac{1}{2}$ cubic meter of air). Both reservoir and main tube will then contain together $1\frac{1}{2}$ cubic meters of air spread over a space of 3 cubic meters, and thus a partial vacuum of $\frac{1}{2}$ an atmosphere will be established, quite sufficient for the removal of faecal matter.

15. Pneumatic Pressure on the Valves. See Drawing, Fig. 3, Sheet I. —As the valves have a diameter of 0·125 meter (the same as the main and side tubes) their surface is 122 centimeters, exposed to an atmospheric pressure of $122 \times \frac{1}{2}$ kilograms = about 60 kilograms, whilst the weight (P) is only 12 kilograms. The pressure is therefore 5 times stronger than what is required to raise the valves (D), which consequently open with great velocity and force the moment their vis inertiae is overcome.

16. Difference of Time in forming the Vacuum in the various Parts of the Main Tube. See Drawing, Fig. 3, Sheet I.—The first and last valve (D) of the main tube (A) will of course not open the very same moment, though very quickly one after the other, because the partial vacuum requires a minute fraction of time to spread itself to the further end of the main tube; for instance, if in main tube (A) the first valve (D) is 10 meters distant and the last valve (D) is 100 metres distant from turncock (H), the vacuum will reach the first valve $\frac{1}{30}$ second and the last valve $\frac{1}{10}$ second after the opening of the turncock.

17. Simultaneous Opening of all the Valves. See Drawing, Fig. 3, Sheet I.—To secure a simultaneous opening of all the valves their weight is reduced in proportion to their distance from the turncock (H), so that their vis inertiae may be overcome so much the sooner, as the vacuum requires more time to spread to each respective valve. Given the distance mentioned in paragragh 16, this reduction of weight must correspond to the difference of time between $\frac{1}{30}$ and $\frac{1}{10} = \frac{1}{15}$ second.

Therefore the first valve must weigh 12 kilograms, the last only 10 kilograms, the intermediate valves in proportion. Hence, in practice, the rule is to reduce the weight of every valve 0·2 kilograms for every 10 meters distance from the turncock (H).

18. Exact Equalisation of Distances and Weights not necessary.—Great exactness in this adjustment of weights is not at all required, because the vacuum will anyhow reach every individual valve soon enough to expose it to an atmospheric pressure 5 or 6 times greater than the weight which keeps it closed. Even with a tolerably great difference in the resistance of the various valves all will open with equal velocity, as actual trials with glass tubes of $2\frac{1}{2}$ centimeters diameter have conclusively proved. The explanation of this fact is the same as that of the effect of an overcharged powder mine. The explosion does not follow exclusively the direction of the least resistance but acts violently in all directions, because the excessive velocity leaves no time for an equalisation of resistances.

19. Increased Velocity in the Opening of the Valves. See Drawing, Fig. 3, Sheet I.—The vis inertiae valves (D) are so constructed that their weight diminishes while opening. The weight P has therefore its point of gravity in the same horizontal plane as the axle of the valve. So soon as the latter turns the weight (P) gets lighter in proportion as does the cosinus of the ascending angle become shorter. The valve would be in perfect equilibrium if the weight (P) stood vertical over the axle, which, however, is prevented by the construction of the valve, so that the same is always compelled to fall back and shut itself the moment the violent rush of air out of the side pipe into the main tube ceases.

20. Slackened Motion of the Valves in Falling Down. See Drawing, Fig. 3, Sheet I.—To prevent a violent slamming of the valves in falling down the upper and lower parts of the same are alike, forming a kind of fan, which strikes the air and thereby moderates the velocity of the fall. This fan on the other hand is no hindrance in the quick opening of the valve, because this opening occurs in a partial vacuum, offering no markable resistance to the fan.

21. Lid of the Valve Box. See Drawing, Fig. 3, Sheet I.—The upper part of the valve box (C) is hermetically closed by a double lid, the lower part of which shuts out the air, whilst the upper part on the level with the street pavement merely serves to protect the lower one from injury.

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22. Hermetic Tightness all over the Subterranean Pipe System not absolutely necessary.—It is not absolutely necessary that all parts of the subterranean pipe system should close hermetically; it is quite sufficient if all parts are only water-tight. The vacuum forming in about two seconds at the most, this time is by far too short for sufficient air to penetrate through any small fissures which may exists here or there so as to interfere in a sensible degree with the pneumatic process. Besides any small fissure or crack will soon fill itself by particles of earth or mud being sucked in out of the adjoining soil.

23. Hermetic Tightness required only in the Reservoir and Turncock. See Drawing, Fig. 3, Sheet I.—The only parts of the subterranean system which must be perfectly air-tight and remain so are the following:—*a*, the reservoir (R); *b*, the turncock (H); *c*, the small piece of pipe connecting both. These parts, however, are comparatively so small that to make and keep them air-tight offers no technical difficulty at all.

24. Reliability of the Turncock. See Drawing, Fig. 3, Sheet I.—The turncock (H) is so constructed that if any derangement does occur it may be examined and repaired in a very short time. For this purpose the turncock is simply lifted out of its box, and the impediment being removed, it is put back again. Nothing is liable to be broken thereby. The box is closed by a double lid, as described in paragraph 21.

25. Fall of the Main Tube.—The main tube receives a fall of at least 1 in 150, and more if practicable, so that the faecal matters driven into it out of the lateral tubes (as long as they have not yet reached the reservoir) can collect through gravity in the lower part of the main tube, whence a new pneumatic shock forces them into the reservoir. This reservoir is therefore located always at the lowest point of the soil upon which the group of houses connected with it stands.

26. Fall of the Lateral Pipes.—The lateral pipes receive a fall of at least 1 in 20 towards the main tube, and more if the levels of the ground permit. The entire network of pipes is thus provided with so strong a fall that the faecal matter moves downward by its own gravity to the lowest parts of the pipes, there to await the repeated pneumatic shocks, which force them first into the main tube and thence further on into the reservoir.

27. Breaks in the Fall of Long Lateral Pipes. See Drawing, Fig. 2, Sheet I.—To prevent a long lateral pipe which receives a fall of 1 in 20

from entering too deeply into the ground, it is from distance to distance bent upwards again, as explained by Fig. 2, Sheet I. in Drawing. A is the diameter of a main tube; B, the lateral pipe connecting this main tube with the house pipe (F) which serves to collect the faecal matter out of all the privies in the house. The breaks in the fall occur at distances of 10 meters from each other, the fall being $\frac{1}{2}$ meter in 10 or 1 meter in 20 on the whole. The upward bends are formed by pieces of pipes bent in a radius of 1 meter. A fall of 1 in 10 is the least allowed, and more is used whenever practicable; 1 in 10 is preferred. By giving, in above-described manner, the branch pipes wave-line grades instead of straight grades pockets are formed in which the faecal matter always collects; hence the pneumatic blast cannot pass over it without action, nor have the gases a free ascent into the house, but are confined every 10 meters or less by hydraulic locks, the last one being under the fall pipe.

28. Pneumatic Evacuation Process with the Improved Vis Inertia Valves. See Drawing, Fig. 3, Sheet I.—After the reservoir (R) has been evacuated by the locomobile air pump the turncock (H) is suddenly opened, allowing the air contained in the main tube (A) to rush into the reservoir, leaving a partial vacuum behind. The air contained in the lateral pipe (B) expands, and thereby lifts up valve (D), this confined air exercising an initial pressure of at least 1 atmosphere; this pressure of course diminishes after the first moment, but the weight of the valve diminishing likewise (see paragraph 19); the valve will open entirely with great velocity. The escape and consequent rarefaction of the air in the lateral pipe (B) causes of course the faecal matter collected in the syphon (K) to move towards the main tube, a movement which occurs simultaneously in all lateral pipes. The consequence is that a great deal of air enters out of the lateral pipes into the main tube and reservoir, re-establishing quickly the atmospheric equilibrium and causing all the valves (D) to fall down and close themselves, while the faecal matter not yet driven into the reservoir settles down by gravitation into the lowest part of the main tube. All this happens in about 30 seconds from the first opening of the turncock (H). As soon as the vacuum meter of the pneumatic locombile indicates this state of things the engine driver shuts turncock (H) and keeps it closed until the air pump has re-established the vacuum in the reservoir, which is done again in about 30 seconds; then the turncock is opened again, and a new

atmospheric shock drives the faecal matter collected in the main tube right into the reservoir. This simple proceeding is repeated as many times as there are breaks in the longest lateral pipe. The whole pneumatic evacuation of a great number of privies all connected with one reservoir is therefore effected by simply opening and shutting several times the turncock (H), allowing a pause of about ½ minute between each opening and subsequent shutting, until all faecal matter by repeated atmospheric shocks has finally been driven into the reservoir (R), the pneumatic locombile keeping constantly in motion all the while. The reservoir in its turn is then emptied by pneumatic pressure into an air-tight waggon cylinder, as has been described in the original Patent.

29. Empty Privies of Uninhabited Houses cause no Disturbance to the Pneumatic Process.—Privies happening to be empty do not prevent in any manner whatever the pneumatic evacuation of the other privies of a group of houses, because each individual lateral pipe has a valve of its own remaining closed by its weight until the vis inertiae of the same is overcome. The internal initial pressure on all the valves is alike, whether this results from atmospheric pressure direct through empty privies or from the expansion of confined air within the lateral pipes, and therefore all valves open simultaneously every time a partial vacuum is made within the main pipe independent of the privies containing anything or not. If a valve is once opened and the privy is empty air alone streams in the lateral pipe; if the privy contains faecal matter, this is carried along with the atmospheric stream which must be produced when part of the confined air of the lateral pipe escapes in the main tube. Even if all the privies connecting with a main tube were empty, the valves of their lateral pipes would open and shut themselves with the same regularity and simultaneousness as when some were full and others empty. There is no time for re-establishing an equilibrium of resistances.

30. The Reservoir an Accumulator of Motive Power and Collector of Faecal Matter.—The reservoir answers a double purpose. When the turncock is closed it accumulates the motive power generated during ½ a minute's work of the locomobile air pump, and expends this with a shock on all the valves when the turncock is opened; after this it collects the faecal matter which this shock has driven out of the entire network of pipes. By transmitting this stored up motive power in such atmospheric

shocks to the vis inertia valves an effect is obtained far more powerful and decisive than a direct sucking of the air pump could produce.

31. Advantages of the Improved Vis Inertia Valves System. See Drawing, Fig. 1, Sheet I.—In addition to the various advantages alluded to in the preceding Specification, there are two others to be explained by Drawing, Fig. 1, Sheet I., representing part of a town with a network of pneumatic pipes and reservoirs.

First Advantage.—A main tube may be put down in a street with valves for the adjacent houses without the necessity of all lateral pipes being laid at the same time. If only one lateral pipe is ready for the reception of faecal matter the main tube may begin its work, which of course greatly facilitates the gradual introduction of the pneumatic system into a town, as the convenience of individual householders may be consulted.

Second Advantage.—Should one or the other privy or its lateral pipe get choked through some object being negligently thrown in which does not belong there, all valves are fastened except that with which the choked privy communicates, and thus the whole power stored up in the reservoir is concentrated on a given point. An alternate opening and shutting of the turncock produces by keeping the air pump constantly at work repeated shocks of nearly a whole atmosphere's power, which of course will effectually remove any obstruction in the privy or pipe in a very short time. The lower opening of the privy funnel is purposely made narrower than the lateral and main tubes, consequently anything passing at all through the narrow outlet of the privy funnel must of course also pass through the lateral and main tube (which are wider than the said outlet) into the reservoir. The fastening of the valves above alluded to is effected by opening the valve box lid (see paragraph 21), and driving in a wooden wedge between the weight of the valve and the side of the box.

Second Improvement,

Referring to new privy arrangements.

32. Pneumatic Privies, 1st Class. See Drawing, Fig. 4, Sheet II.—These new privies are so constructed that they may be emptied and cleaned through atmospheric blasts. Faecal matter disappears under them immediately after production, the same as in waterclosets. The vertical pipe (F) receives the excrements dropping down from the

various floors of the house. The funnel (T) is closed by a valve (D) provided with a counterweight (P) of 4 kilograms. This valve opens the moment a partial vacuum occurs in the vertical pipe through the evacuation process described in paragraph 28. The wider this valve opens the lighter the weight gets (see paragraph 19). The upper part of the funnel is double, and the space between both parts ($\frac{1}{2}$ centimeter wide) is connected with a ventilation pipe (E) reaching up to outside the roof of the house. In daytime this ventilation pipe carries off the exhalations of the funnel sides, whilst at night this same pipe admits the atmospheric current required for the evacuation (see paragraph 28). The friction due to this powerful atmospheric current keeps the funnel clean. Valve (D) likewise opens entirely, and thus gets out of the way of falling matter as often as a person sits down upon the privy, so that no excreta can ever adhere to it. The front part of the sitting board turns upon pin (O), lowers itself 2 inches and presses upon the rod V, which by its knobs (*j*) and the lever (X) opens valve (D). As soon as the person rises the sitting board rises likewise slowly through the weight (Z), and valve (D) shuts itself by its own gravitation. The sitting board as well as the upper part of the funnel (T) may at any time be taken off if cleaning should be required. All moveable parts are accessible so easily that any repairs can be effected with very little trouble.

33. Pneumatic Privies, 2nd Class. See Drawing, Fig. 5, Sheet II.—Second class privies are much cheaper and more simple in their construction, which is as follows:—Valve (D) is kept closed by a weight (P) in a perpendicular line, so that no matter can adhere to it. The lower part of the funnel forms a hydraulic trap of so small a capacity that each new contribution of faecal matter forces those already there into the vertical pipe. Ventilation pipe (E) carries off the exhalations during daytime and admits at night the atmospheric current for pneumatic evacuation.

34. Hydraulic Trap of the Vertical Pipe. See Drawing, Figs. 6 and 2, Sheets I. and II.—The vertical pipe of both classes of privies is closed by a hydraulic trap calculated to contain the daily excretae of 6 persons, say about 6 litres. Any surplus over that quantity (generally only the liquid part, runs off into the lateral pipe (see Fig. 2.) This matter (mostly composed of solids) collecting in this trap is carried off into the lateral pipe by a pneumatic shock the moment a partial vacuum is formed, as described in paragraph 28.

35. Privies for the Poorer Classes.—Privies for the poorer classes, with whom cheapness is a main object, open into a vertical pipe with oblique funnels for the various floors of the house. This vertical pipe reaches above the roof for ventilation, whilst the lower end is provided with a hydraulic trap, as described in paragraph 34.

36. Pneumatic Privies in Groups for Large Establishments. See Drawing, Figs. 7 and 8, Sheet II.—For schools, factories, military barracks, and other large establishments privies are arranged in groups, as shown in Drawing, Sheet II., Figs. 7 and 8. Fig. 7 shows the privies placed in a straight line, Fig. 8 on the contrary privies grouped in a circle, pissoirs being included in both cases. Each single privy consists of an iron funnel glazed inside, with a small hydraulic trap below, calculated to contain the daily evacuation of two to three persons. Equilibrium pipe (G) connects all privies, so that the same level of faecal matter is maintained in all. As the quantity contained in each is therefore the same the vis inertiae of the respective masses must also be alike in all the privies, and consequently a partial vacuum formed in the collecting pipe (L) or in the collecting funnel (M) will simultaneously evacuate all these privies. As in large establishments, such as barracks or schools, great quantities of faecal matter are daily to be removed the pipe connecting with them is made a main tube (A), and provided with a turncock, so that the pneumatic power may be so much more concentrated.

37. Pneumatic Privies Grouped in Different Floors of a Large Building. See Drawing, Figs. 7 and 8, Sheet II.—If in a large establishment the groups of privies are situated one above the other on different floors, there is a vis inertia valve (D) either at the end of the collecting tubes (L, Fig. 7) or at the bottom of the collecting funnels (M, Fig. 8), this valve being in both cases kept closed by a weight P. The vertical pipe is closed air-tight at the top, so that a partial vacuum may be formed in its entire length before the vis inertiae valves open themselves. The moment the valves open the evacuation takes place simultaneously in all the privies, the entire faecal mass plunges into the airless vertical pipe, and is driven like a piston through the main tube into the reservoir.

Third Improvement,

Referring to an apparatus which can be put at will in gear for measuring the quantity of faecal matter forced by pneumatic pressure

out of the subterranean reservoir into a waggon cylinder, to indicate whether the latter is sufficiently filled or whether there is still room for the contents of another reservoir, and which can be put out of gear when the waggon is driven away.

38. Two Domes on the Top of the Waggon Cylinder.—See Drawing, Fig. 9, Sheet II.—The atmosphere presses into the iron air-tight waggon cylinder (N) all faecal matter out of the subterranean reservoir the moment turncock (Q) is opened. This waggon cylinder is provided with two domes (U, U,) each having a pipe with a turncock leading to the hind part of the waggon cylinder. One of these pipes is coupled by means of a flexible hose with the subterranean reservoir, the other with the locomobile air pump, which through this double connection can establish a vacuum simultaneously in the waggon cylinder and subterranean reservoir, at the same time there is no danger of any spray or drops of faecal matter being sucked into the air pump, such drops being invariably precipitated on their way from one dome to the other.

39. Description of the Measuring Apparatus. See Drawing, Fig, 9, Sheet II.—The hindmost dome of the waggon cylinder contains the measuring apparatus, consisting in a hollow float (*a*), which rises and descends along rod (*b*), and can be lowered by means of two light chains (*c*) and the pulleys (*d*). Rod (*b*) does not reach quite down to the bottom of the cylinder so that no rags, etc. can remain hanging to it when the waggon is emptied. The axle of the pulleys (*d*) passes through an air-tight stuffing box to outside the dome, and carries there a spiral spring, which unwinds the chains when the float falls, and winds them up when it rises again, being so adjusted as to maintain said chains (*c*) always in equilibrium. The axle is further provided with a small cog wheel acting upon a larger one which carries the indicator (*e*). The proportion between these two cog wheels is such that a whole revolution of the indicator (*e*) corresponds to a whole rise of the float (*a*). If the indicator shows zero then the cylinder is quite empty, and if the float rises the indicator turns around until it points one degree before zero; then the cylinder is quite full. At this point the dial plate is provided with a catch for arresting the indicator, thus keeping the float suspended at its greatest height. This prevents the latter from dancing up and down with the liquid matter whilst the waggon is in motion, and thus guards the whole of this guaging machinery against the wear due

to such incessant and excessive action. The indicator is provided with a knob, so that it can be used as a crank for winding the float easily up to the point where it can be stopped.

Fourth Improvement,

Referring to the apparatus for filling barrels out of the waggon cylinders in a perfectly inodorous manner.

40. Decanting Station and Store house for Dung Barrels. See Drawing, Fig. 10, Sheet III.—In the hinder part of the building is a sunk recess (I) or inclined plane, to which lead two ramps (W), one for rolling down the empty barrels, the other (which is of an easier gradient) for rolling up the barrels when filled with manure. The centre part of the floor is fenced off to serve for storage room for the barrels, both empty and filled. Opposite the middle of this recess (I) is the place to which the cylinder waggons are to be backed up for decanting their contents into barrels.

41. Decanting Apparatus. See Drawing, Fig. 11, Sheet III.—The dung hose (*f*) is coupled to a turncock (*m*) fastened into the floor, beneath which hangs a large basket (*g*). A dung measure (*h*) is suspended below this on one end of a large balance (*l*). The other end of this balance holds a scale with a number of weights. The dung measure (*h*) is also provided with a turncock (*n*), and this like the upper cock has a long handle for working it with ease. The upper turncock (*m*) is connected through a leather hose (*o*) with the dung measure (*h*), so that this can freely follow up and down the motion of the balance (*l*). The leather hose (*o*) is fitted with a number of iron rings so as to keep its folds neatly. The lower turncock (*n*), just fits into the bung-hole, which is alike for all classes of barrels. The balance scale (*p*) is now loaded with a number of weights corresponding to the exact contents of the dung barrel about to be filled.

42. Guaging and Filling of the Dung Barrels. See Fig. 11, Sheet III. of the Drawing.—To suit the individual requirements of farmers various classes of barrels are kept, containing, respectively 3, 4, 5, 6, or even more, hundredweights of liquid dung. All barrels are guaged and marked according to their contents in weight. The filling operation is then as follows:—After the scale (*p*) has been loaded with the weights corresponding to the guage of the barrel about to be filled dung hose (*f*) of the waggon cylinder is coupled to turncock (*m*) in the

floor. The turncock of the waggon and the turncock (*m*) are then opened, thus causing the liquid dung to run into the basket (*g*), which retains all rags, bones, etc., etc., so that no solid substances whatever reach the dung measure (*h*). As soon as the latter is filled with the quantity of dung corresponding to the number of weights lying in the scale (*p*) the balance will assume a horizontal position, upon which the operator shuts cock (*m*), presses the dung measure still further down until the lower cock (*n*) fits into the bung-hole of the barrel, and fastens the dung measure in this position by means of a hook fixed to a wall of the building. After this the lower cock (*n*), is opened, the barrel will be filled then exactly full without spilling, because its contents have been determined beforehand by weights corresponding to its proper guage.

44. Escape of Air out of the Barrel during Filling. See Drawing, Fig. 12, Sheet III.—The lower turncock (*n*) has a ventilation hole (*s*), which communicates through a thin caoutchouc hose with ventilation pipe (*t*). A similar hose (*u*) connects a ventilation hole in the lid of the dung measure (*h*) with the same pipe (*t*) which carries off all gases escaping during the filling operation above the roof of the building, where if necessary these gases may pass through the grate of a small fire. A caoutchouc ring is laid between the turncock (*n*) and the barrel to prevent all escape of gas there.

45. Bung Hole of the Dung Barrels. See Drawing, Figs. 12 and 13, Sheet III.—The bung hole of the barrels is provided with a cast-iron ring in which a bung with a small safety valve (*k*) can be screwed in. This valve opens itself whenever an accumulation of gases takes place strong enough to burst the barrel unless this outlet were provided.

Fifth Improvement,

Referring to the Apparatus for Ploughing the Fresh Human Manure direct into the Soil.

46. Improved Manuring Plough. See Drawing, Fig. 14, Sheet III.—A two-wheeled cart carries on the prolongation of its shaft two blocks (1) on which a dung barrel can be laid right across the track of the car. Behind the cart hangs a wooden frame, having in its lower beam a number of strong iron hooks set in a row about 3 inches apart, on each of which a light plough may be alternately hung just as may be needful for drawing a furrow at the exact place where it is required. This

enables the labourer to spread the liquid dung in parallel furrows on a track of at least one meter wide, without changing the direction of the cart.

47. Loading and Fastening the Dung Barrel. See Drawing, Fig. 14, Sheet III.—In front of the cart there is a windlass (3) worked by means of a crank (4), while behind two skids (S) are hung leading up to the rear end of the cart. A rope slung around the dung barrel is hooked with one end to the rear part of the cart whilst the other end is fastened to the drum of the windlass. By turning the crank (4) the barrel is wound up until it lies across the blocks (1). The barrel is then turned round until the bung hole lies upward. The iron bung is screwed out, a cock (5) inserted in its place, and connected with a two-inch dung hose (*w*). The barrel is then turned round again until the cock is below, the rope is tightened with the windlass, and fastened in the right position by means of a small pawl working on a ratchet of the windlass. To facilitate turning the barrel backwards and forwards small rollers are set into the blocks (1). The skids (S) which served for hoisting up the barrel are during the ploughing of course laid aside.

48. Dung Nozzle and Rake. See Drawing, Fig. 14, Sheet III.—The dung hose (*w*) terminates in a nozzle (6), and reaches to behind the ploughshare, where it squirts the liquid manure into the furrow just drawn. A rake (8) behind the ploughshare covers the dung with earth immediately after so that all evaporation of ammonia is prevented.

49. Regulating the Dung Stream and Closing the Dung Hose. See Drawing, Fig. 15, Sheet III.—On the lower beam of the wooden frame there is a regulator, consisting of an iron shoe (*y*) on which the dung hose rests; this shoe can be shifted to the right or to the left on the beam (2) just as the position of the plough requires it. The shoe (*y*) has two lugs bearing a lever (*x*), the lower part of which is broad and flat. A spring (*z*) presses this part of the lever down upon the dung hose, flattening and thereby closing it the moment the upper part of the lever is set free by slackening a cord which the laborer holds in his hand whilst managing the plough. On the other hand a more or less strong pull at this cord opens the hose more or less, and thus regulates the flow of the dung.

50. Manipulation of the Manuring Plough. See Drawing, Sheet III., Fig. 14.—Whilst a horse pulls the cart the laborer draws a furrow with

the plough hooked on behind, pulls the cord, and thereby allows the liquid manure to be injected into the soil, while the rake (8) closes the furrow immediately after. If a stone or root obstructs the track the labourer slackens the cord, thereby closing the dung hose entirely, and unhooks or turns the light plough (paragraph 46); he can thus remove or avoid the obstacle.

51. Division of the Fields into Planting Beds and Manuring Stripes.—The fields are divided into alternate planting beds and manuring stripes, the latter being just wide enough for one or two horses to pull through the manuring plough just described. The planting beds are about double that width. The following year the new manuring stripes are laid just in the middle of the old planting beds, in other words, the alternate position of both is just reversed, so that those parts of the field which have been manured the preceding year are now used as planting beds.

52. Manuring Stripes in Winter Time.—In winter time the liquid manure is either ploughed in so as to fall on top of the ground, and then covered with snow instead of with earth, or poured out into furrows drawn beforehand ere a hard frost sets in. In both cases fermentation cannot take place, and escape of ammonia and all bad stench is prevented by the low temperature. When a thaw sets in the manure speedily percolates into the soil with the snow water, or if necessary can be finally covered up with earth by a fresh ploughing in.

53. Advantages of this Dung Stripe System.—The advantages of this new agricultural system may be shortly summed up as follows:—1stly. There is all the year round a place for storing up fresh faecal matter as a fertiliser in the field itself without losing any organic ingredients, so that agriculture is greatly benefitted, while at the same time the excreta are finally disposed of and need no further care or treatment. 2ndly. All expenditure for manufacturing poudrette or analogous matter being avoided, the farmer gets his manure very cheap and in a highly concentrated form. A far greater quantity of atmospheric nourishment is procured both to the growing crops and the soil itself by the air passing through the manuring stripes and entering into the soil through the furrows repeatedly drawn at all seasons of the year. The dung stripes besides give easy access to all parts of the field, which can thus so much the better be kept clean of weeds.

Liernur's Improvements in Removing and Utilizing Sewage.

General Summary of my Improvements.

I. Improved Vis Inertia Valves. See paragraphs 7 to 31, Drawing, Sheet I., Figs. 1 to 3.—I, the undersigned, claim as my Invention a new mode of closing the lateral pipes of a pneumatic sewerage system by certain self-acting valves which I term vis inertiae valves, which are kept closed by a weight so calculated that its vis inertia requires more time to be overcome than the air confined in the main tube requires time to rush into a reservoir out of which the air has been exhausted, causing in the main tube a partial vacuum to be established along its entire length before a single valve is opened and strong enough to overcome the vis inertia of said valves, and to open them so as to set thereby the faecal matters in motion, which may be contained in all or several or one privy, substantially as described in all its details in the preceding Specification from paragraph 7 to paragraph 31, and illustrated in the accompanying Drawing, Figs. 1 to 3, Sheet I.

II. Improved Pneumatic Privies. See paragraphs 32 to 37, Drawing, Figs. 4 to 8, Sheet II.—I, the undersigned, further claim as my Invention a new construction of privies, the funnels of which are provided with self-acting vis inertia valves or self-acting vis inertia syphons in such a manner that such privies are emptied pneumatically, when the said valves or syphons open themselves after and in consequence of a partial vacuum being established along the whole length of the vertical pipe in which they discharge, substantially as described in all its details in the preceding Specification from paragraph 32 to paragraph 37, and further illustrated in the accompanying Drawing, Figs. 4 to 8, Sheet II.

III. Measuring Apparatus for Waggon Cylinders. See paragraphs 38 and 39, Drawing, Fig. 9, Sheet II.—I, the undersigned, further claim as my Invention a measuring apparatus set into a hermetically closed waggon cylinder, and consisting in a float which indicates the contents of the cylinder by rising and falling, thereby setting in motion a hand on a dial, which hand serves also to wind up the float and to keep it suspended at its greatest height whilst the waggon moves along, so as to prevent the guaging machinery from being injured or worn out by the dancing up and down of the liquid, substantially as described in all its details in the preceding description in paragraphs 38 and 39, and further illustrated in the accompanying Drawing, Fig. 9, Sheet II.

Liernur's Improvements in Removing and Utilizing Sewage.

IV. Inodorous Decanting Apparatus for Dung Barrels. See paragraphs 40 to 45, Drawing, Figs. 10 to 13, Sheet III.—I, the undersigned, further claim as my Invention an apparatus for decanting inodorously the contents of waggon cylinders into air-tight dung barrels. This apparatus consists mainly in an air-tight dung measure hung up at one end of a balance, while the other end carries a number of weights laid into a scale which correspond to the guage of the barrel to be filled, and the descent of the dung measure indicating the exact moment when the operator has to close the upper or inlet cock, whilst the loaded scale is secured against too quick a descent by a perforated piston moving in a subterranean cylinder filled with water, substantially as herein-before described and illustrated on the accompanying Drawing.

V. Ploughing and Manuring Apparatus. See paragraphs 46 to 53, Drawing, Figs. 14 and 15, Sheet III.—I, the undersigned, further claim as my Invention an apparatus for simultaneously ploughing, manuring, and closing the furrows with the following four peculiarities:—1, a furrow may be drawn and manured at any point over the whole width of the track without the cart leaving it; 2, the plough may be taken off from the cart at a moment's notice for drawing a new furrow, avoiding stones or roots, or using the cart for some other purpose; 3, the same windlass which hoists the barrel upon the cart fastens it there; 4, the flow of the manure is regulated by a spring which presses upon the dung hose or closes it altogether according to the desire of the operator, and by his merely slackening a cord which he holds in his hand and which lifts that spring or lets it go, substantially as described in the preceding Specification from paragraph 46 to paragraph 53, and further illustrated in Drawing, Figs. 14 and 15, Sheet III.

In witness whereof, I, the said Charles Thieme Liernur, have hereunto set my hand and seal, this Nineteenth day of October, in the year of our Lord One thousand eight hundred and sixty-nine.

CHARLES T. LIERNUR. (L.S.)

LONDON:
Printed by George Edward Eyre and William Spottiswoode,
Printers to the Queen's most Excellent Majesty. 1869.

A.D. 1869. May. 3. N°. 1352.
LIERNUR'S Provisional Secification.

FIG. 1.

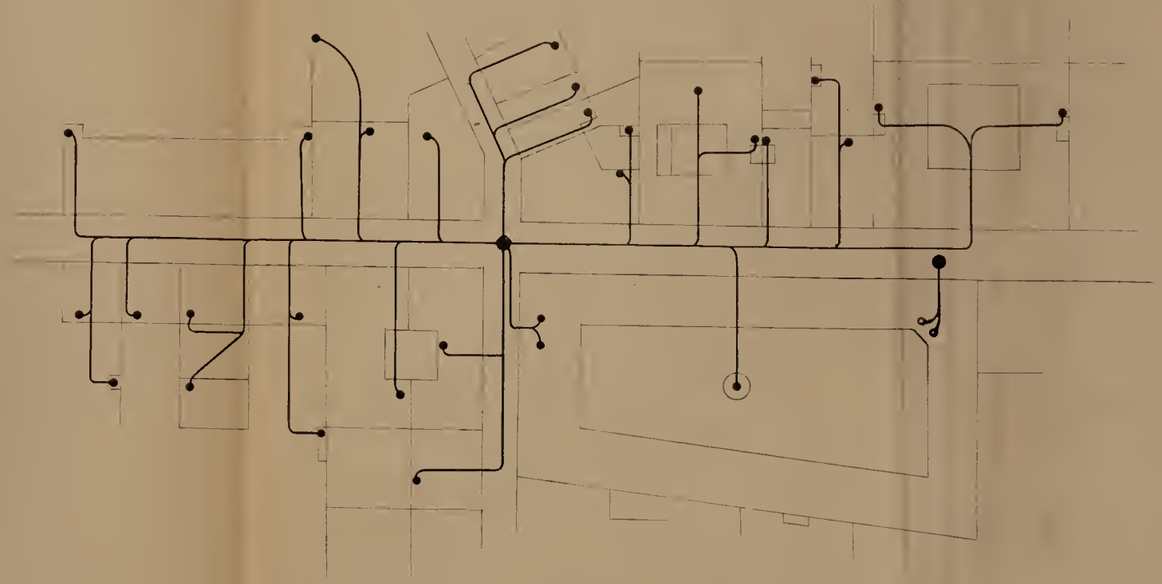

FIG. 2.

The drawing left with Provisional Specification is partly colored.

Drawn on Stone by Malby & Sons

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Printers to the Queen's most Excellent Majesty 1869

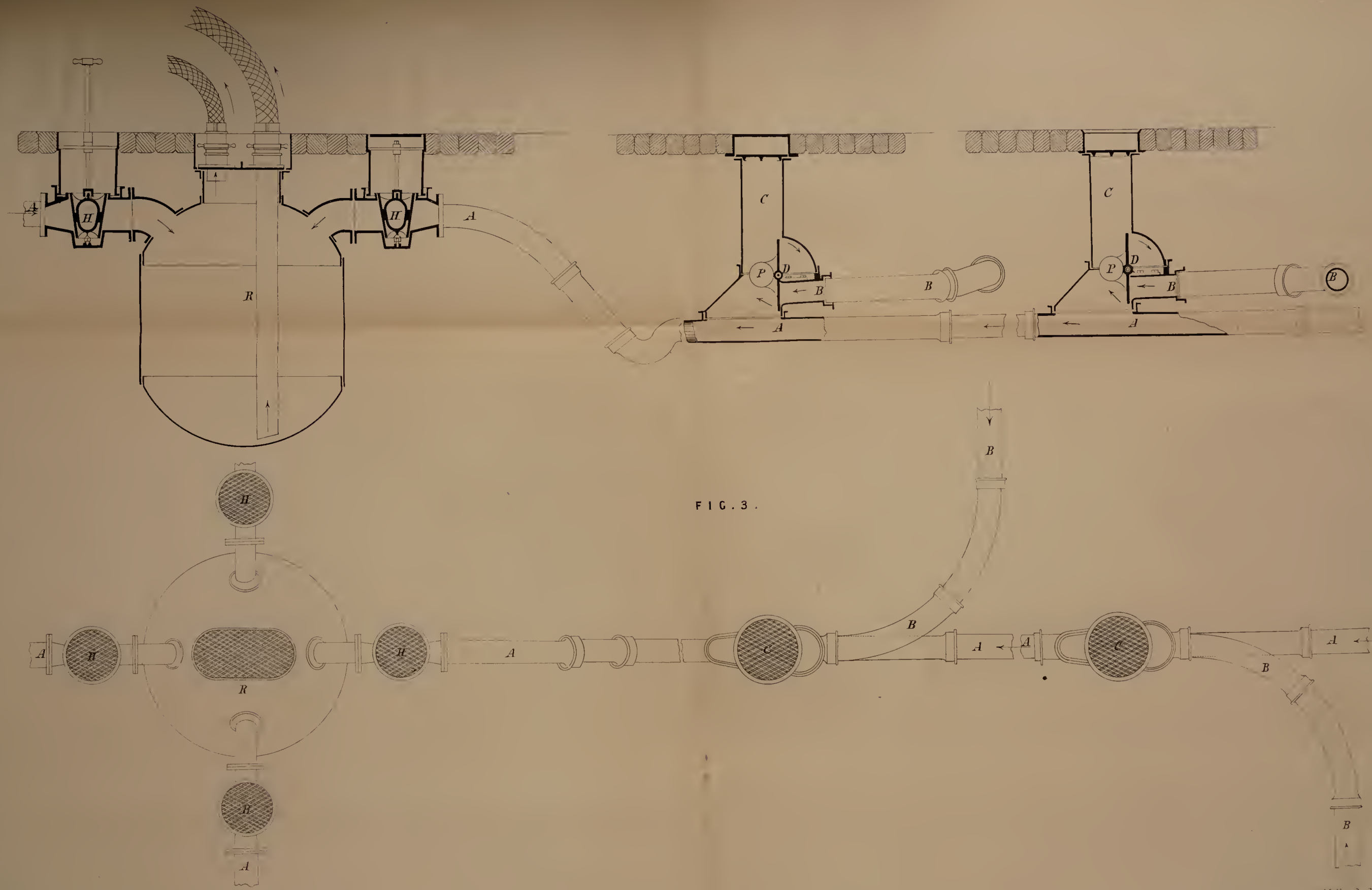

FIG. 3.

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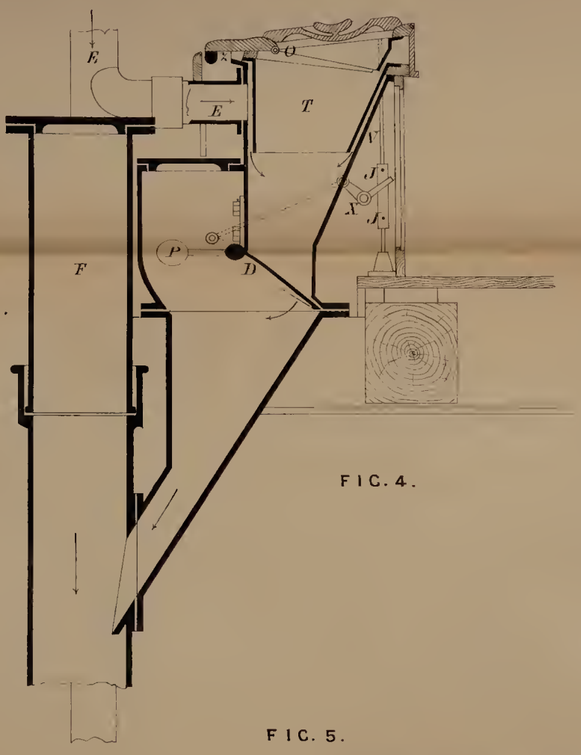

FIG. 4.

FIG. 5.

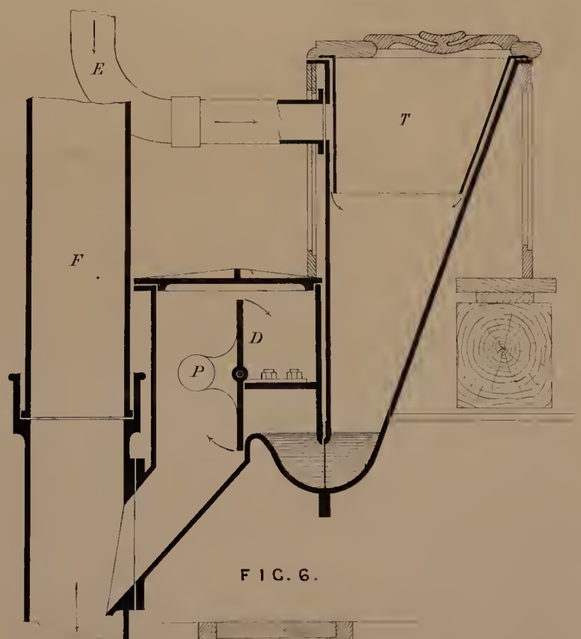

FIG. 6.

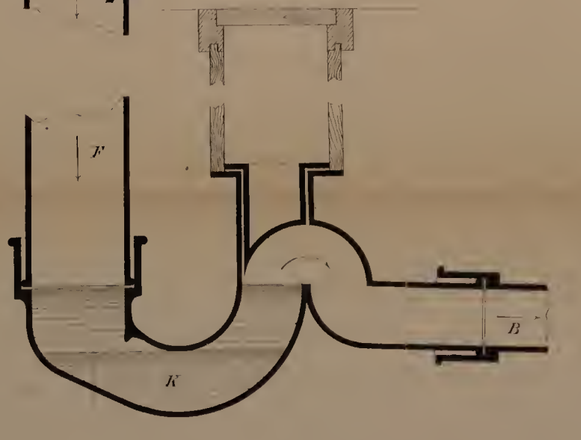

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FIG. 7.

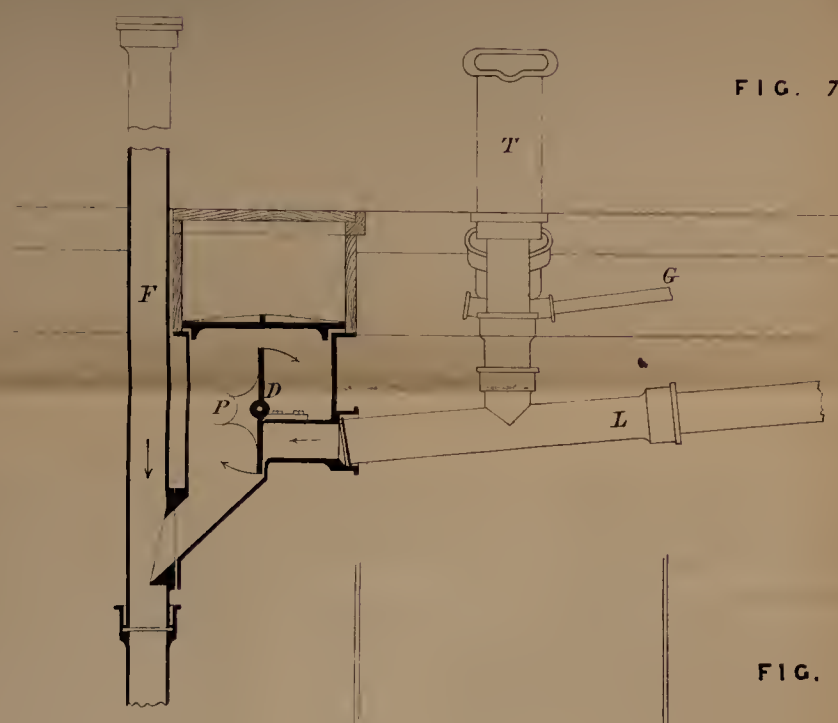

FIG. 7.

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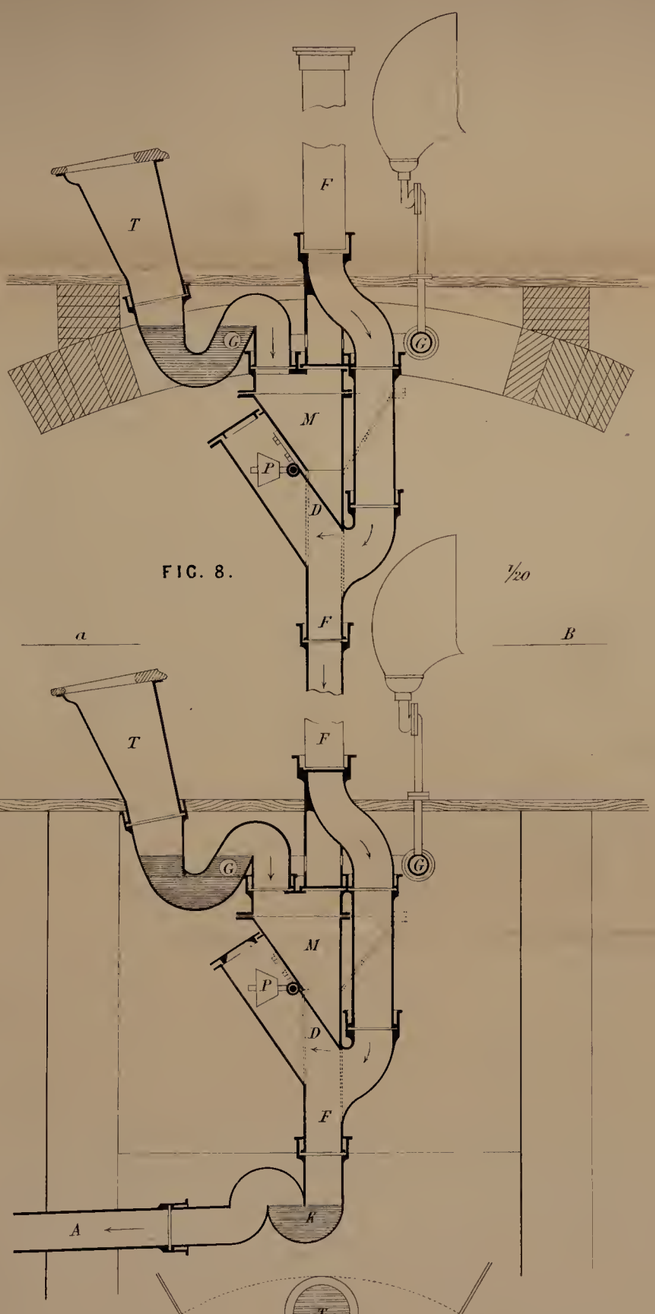

FIG. 8.

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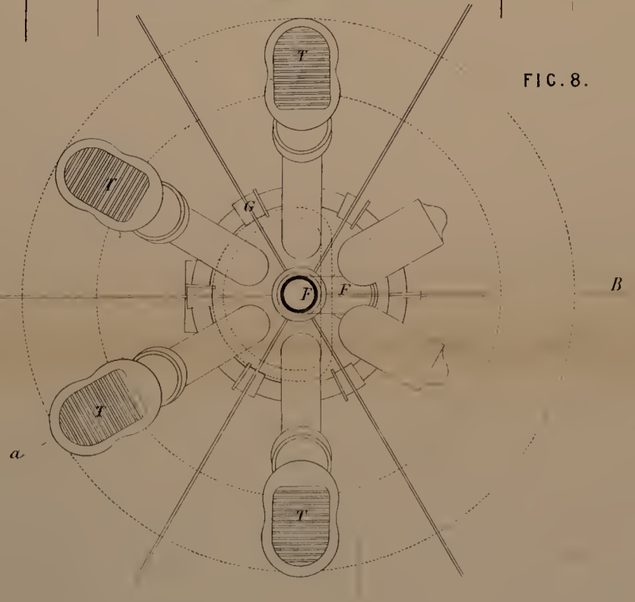

FIG. 8.

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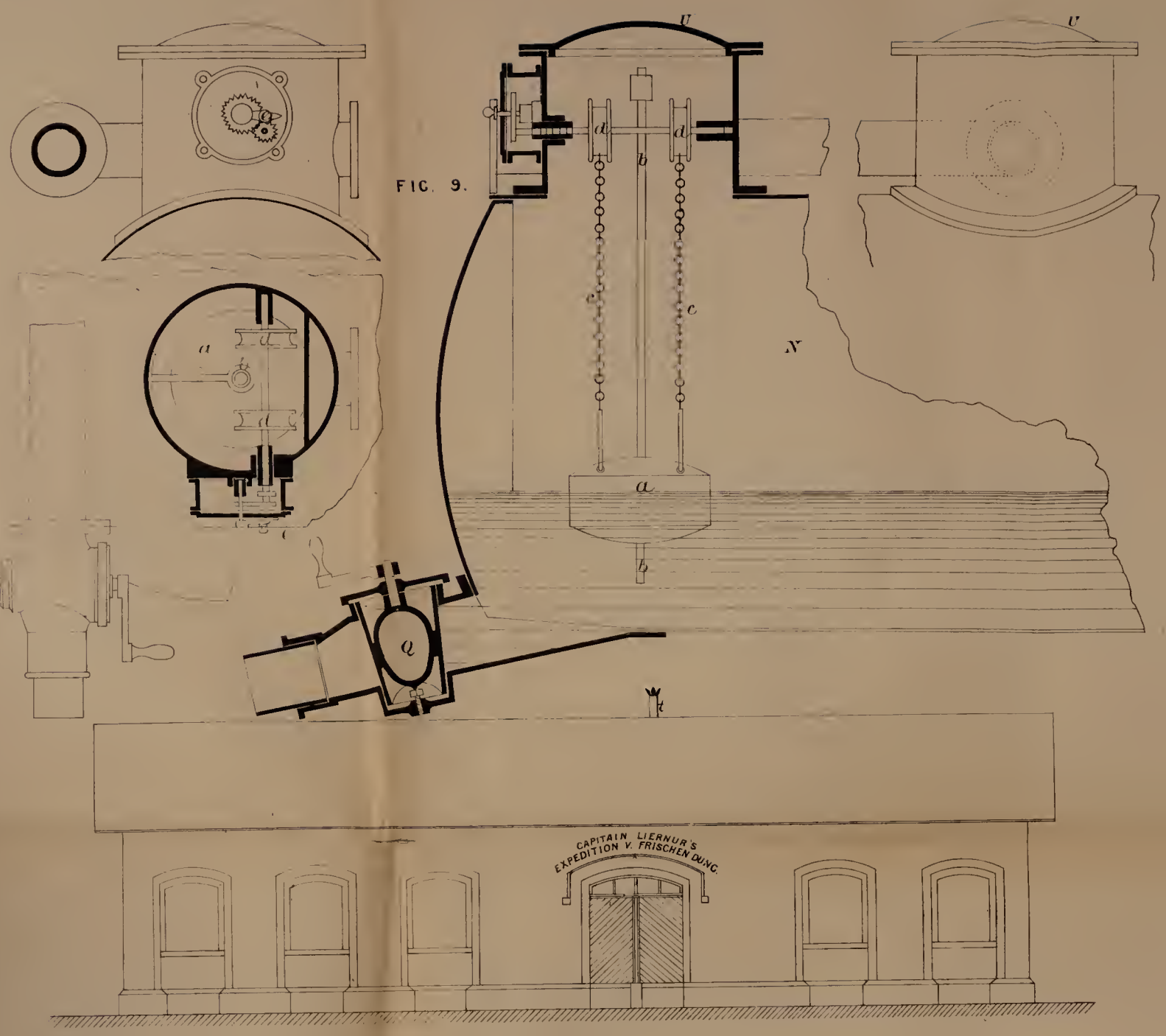

FIG. 9.

FIG. 10. 1/100

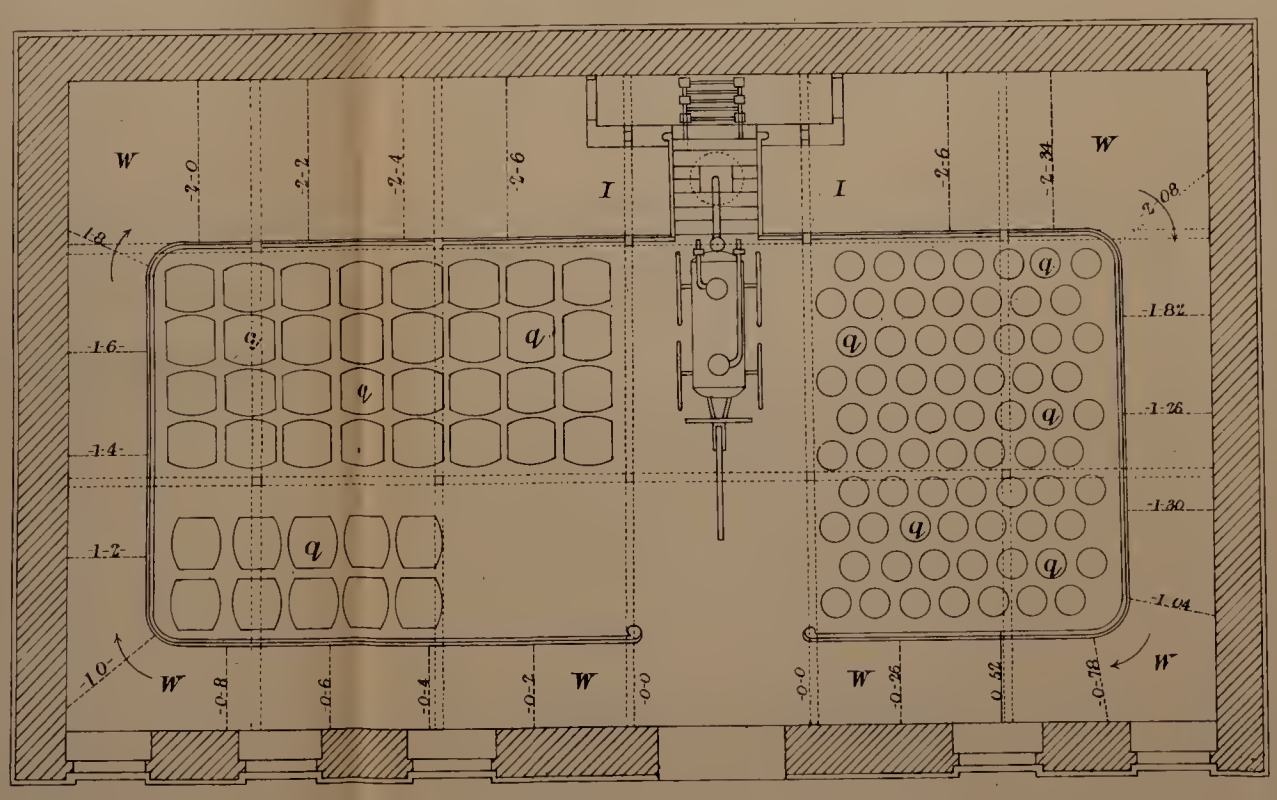

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FIG. 11.

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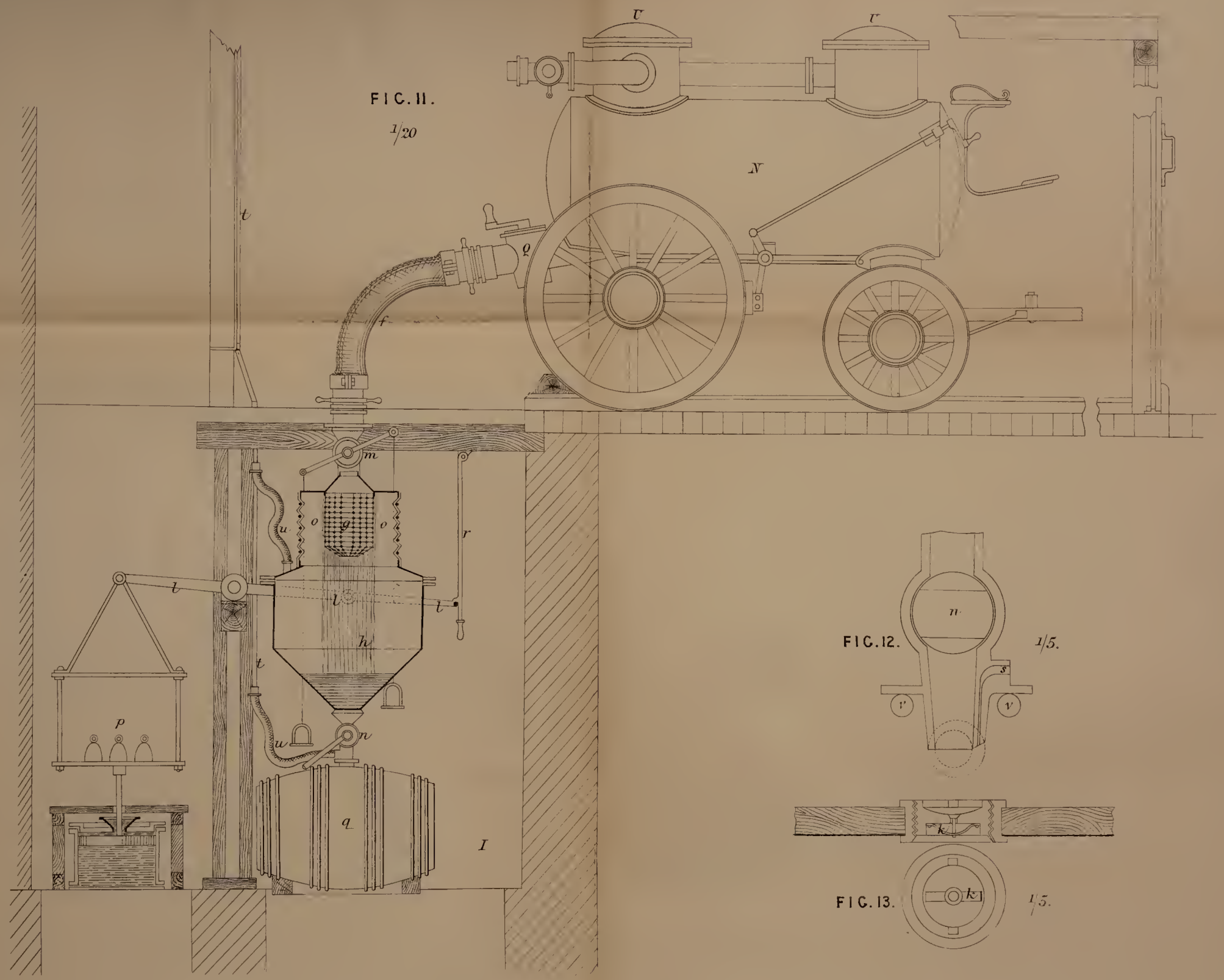

FIG. 12. 1/5.

FIG. 13. 1/5.

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FIG. 14. 1/20

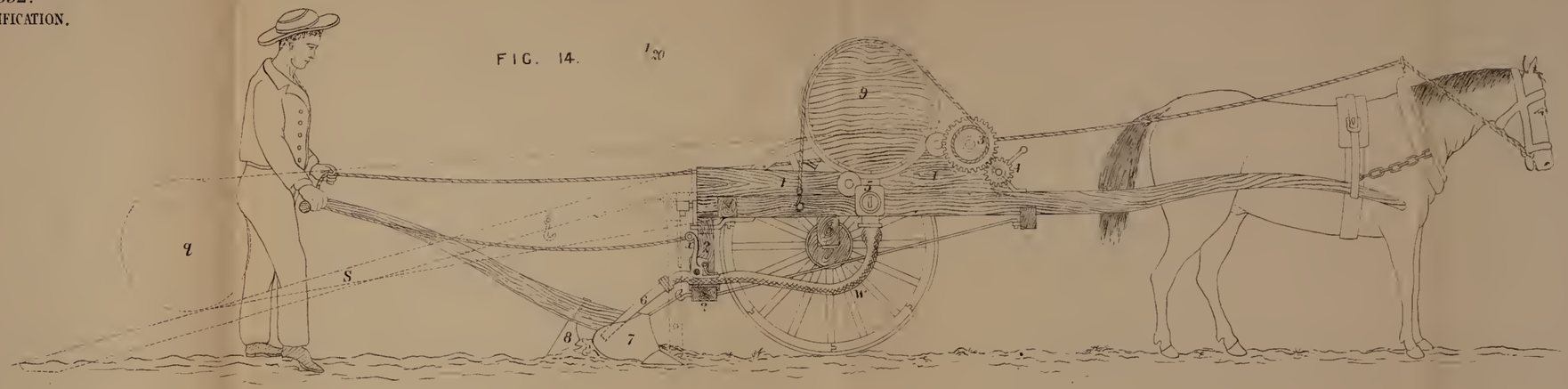
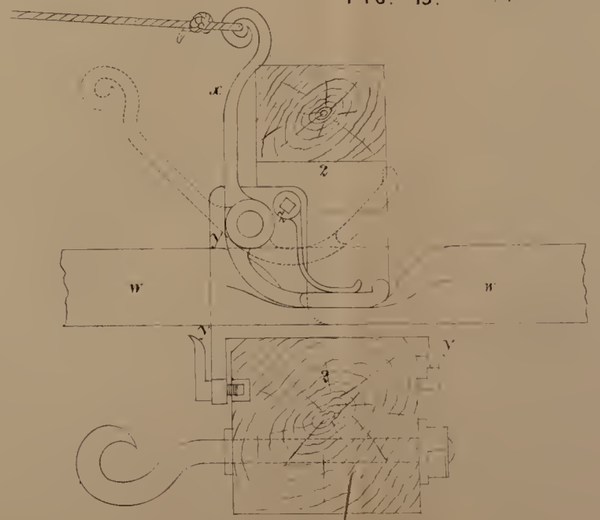


FIG. 15. 1/4



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Drawn on Stone by Maty & Sons

A. D 1869. May 3. N° 1352.
LIERNUR'S Specification.

(3 SHEETS)
SHEET 1

FIG. 3.

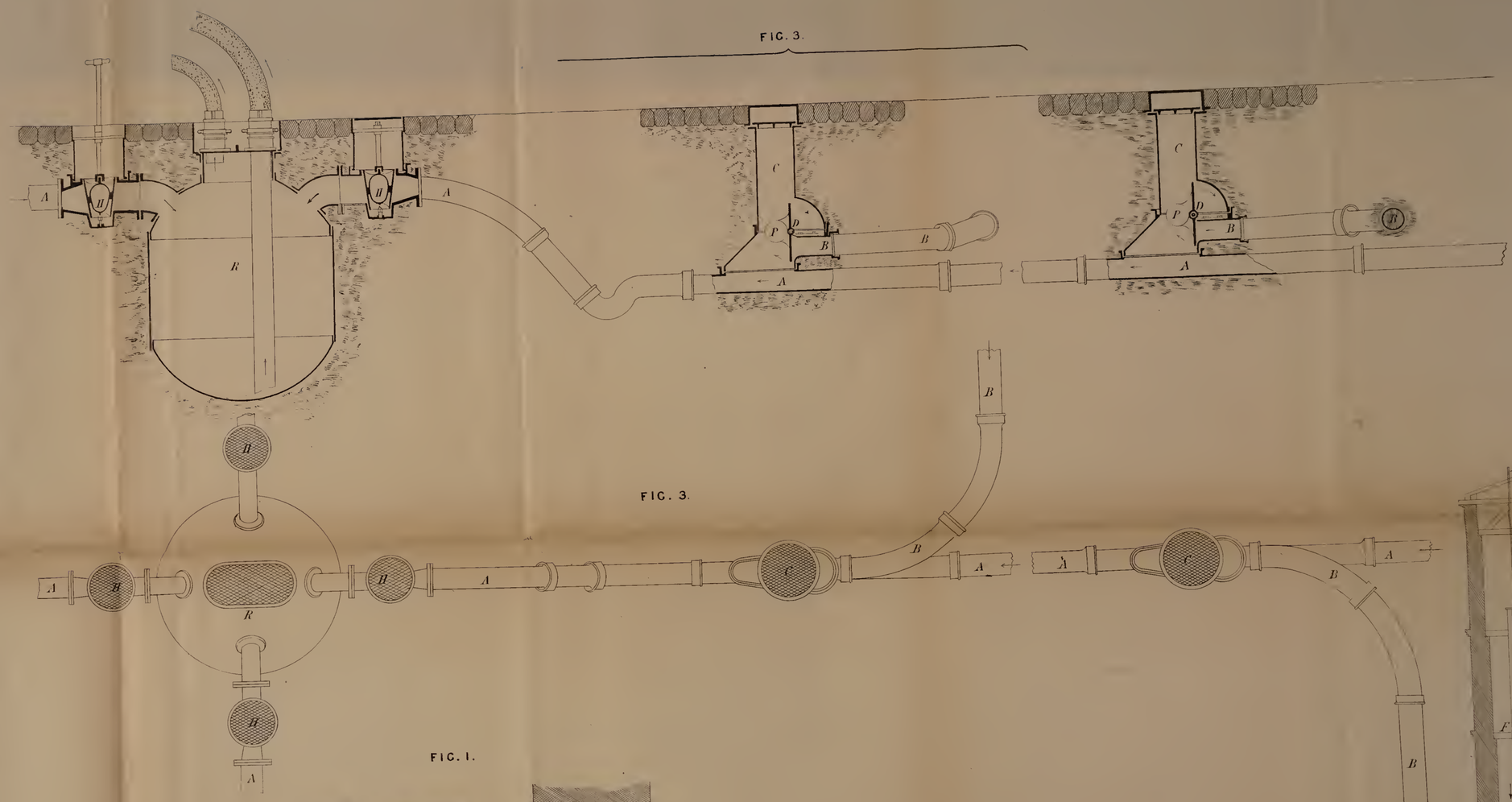

FIG. 3.

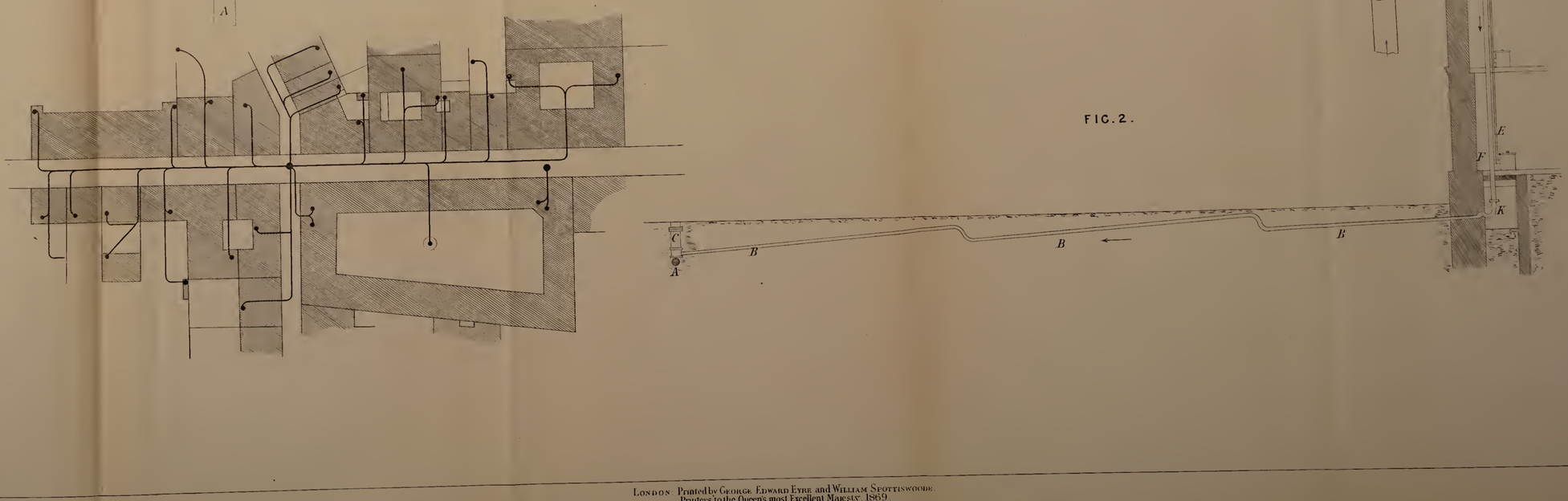

FIG. 1.

FIG. 2.

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Drawn on Stone by Maxy & Sons

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Printers to the Queen's most Excellent Majesty. 1869.

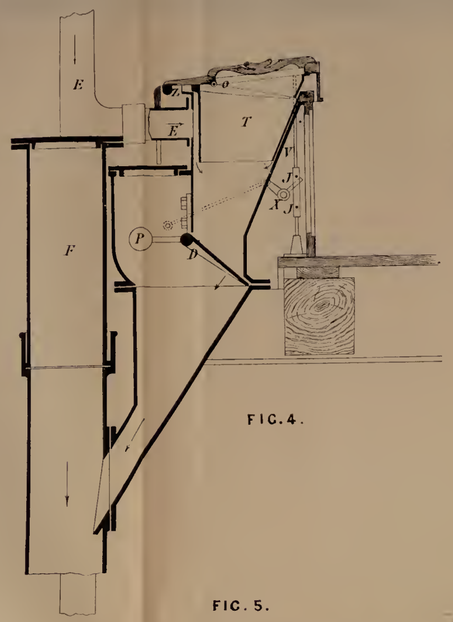


FIG. 4.

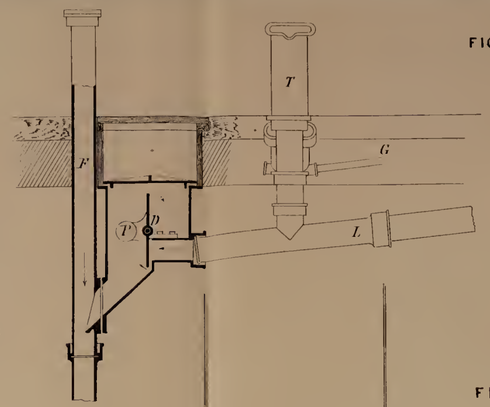
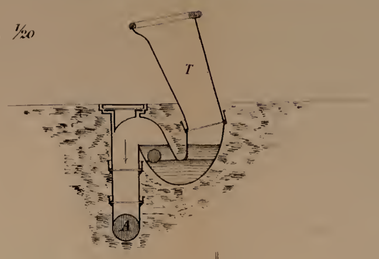


FIG. 7. 1/20



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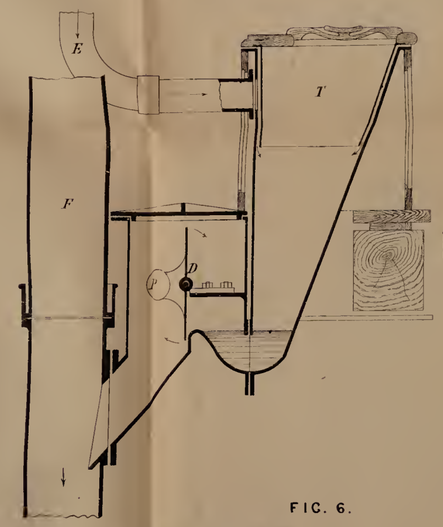
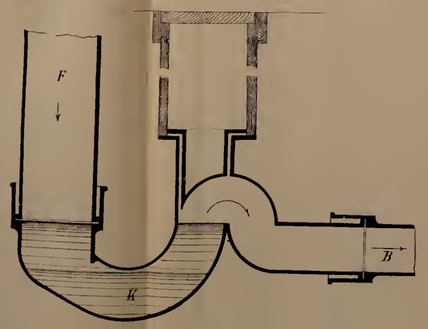


FIG. 6.



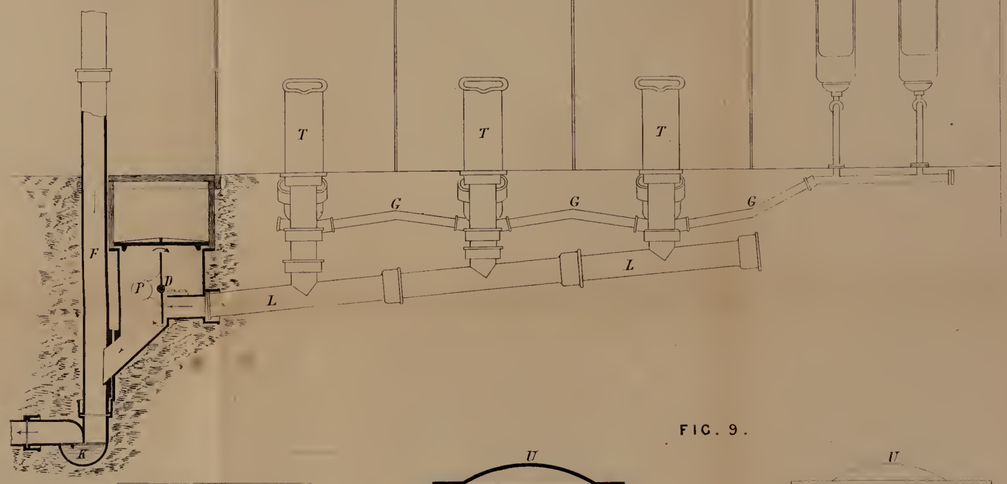


FIG. 7.

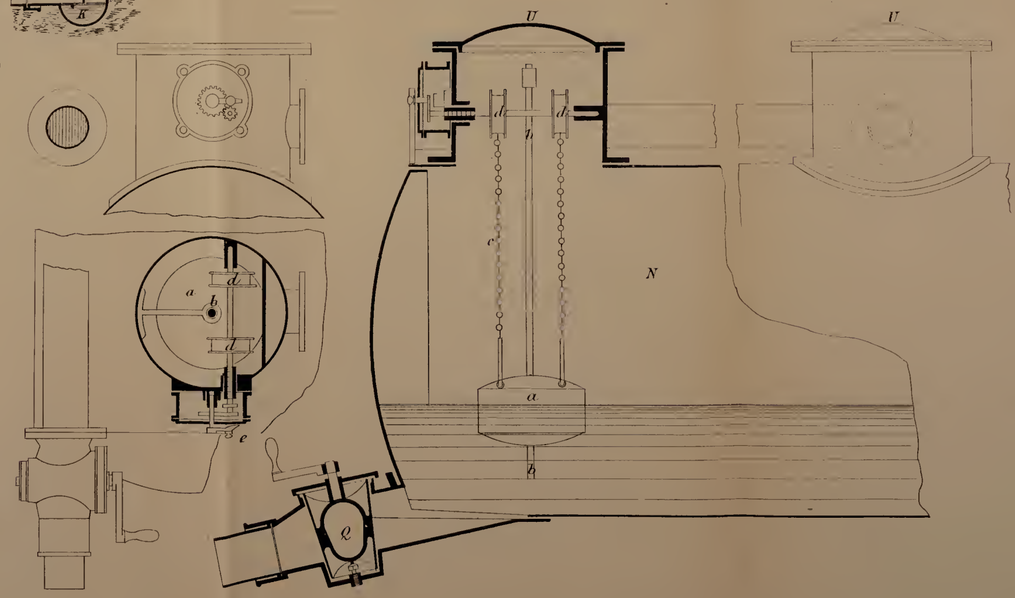


FIG. 9.

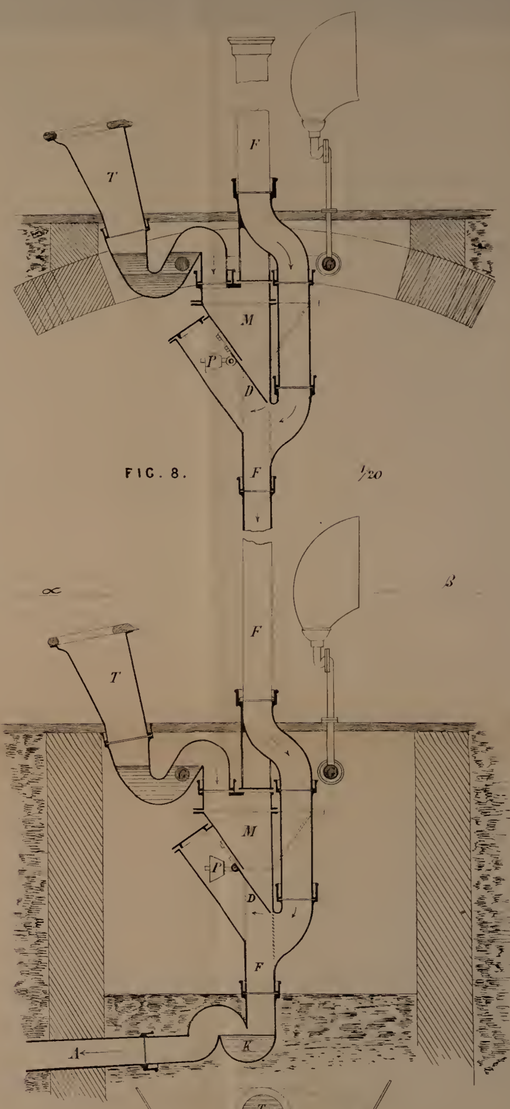


FIG. 8. 1/20

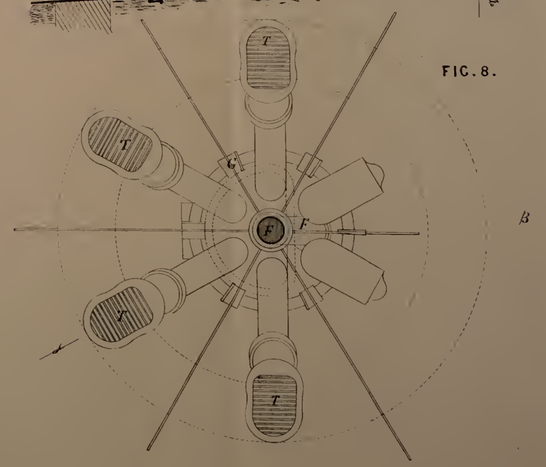


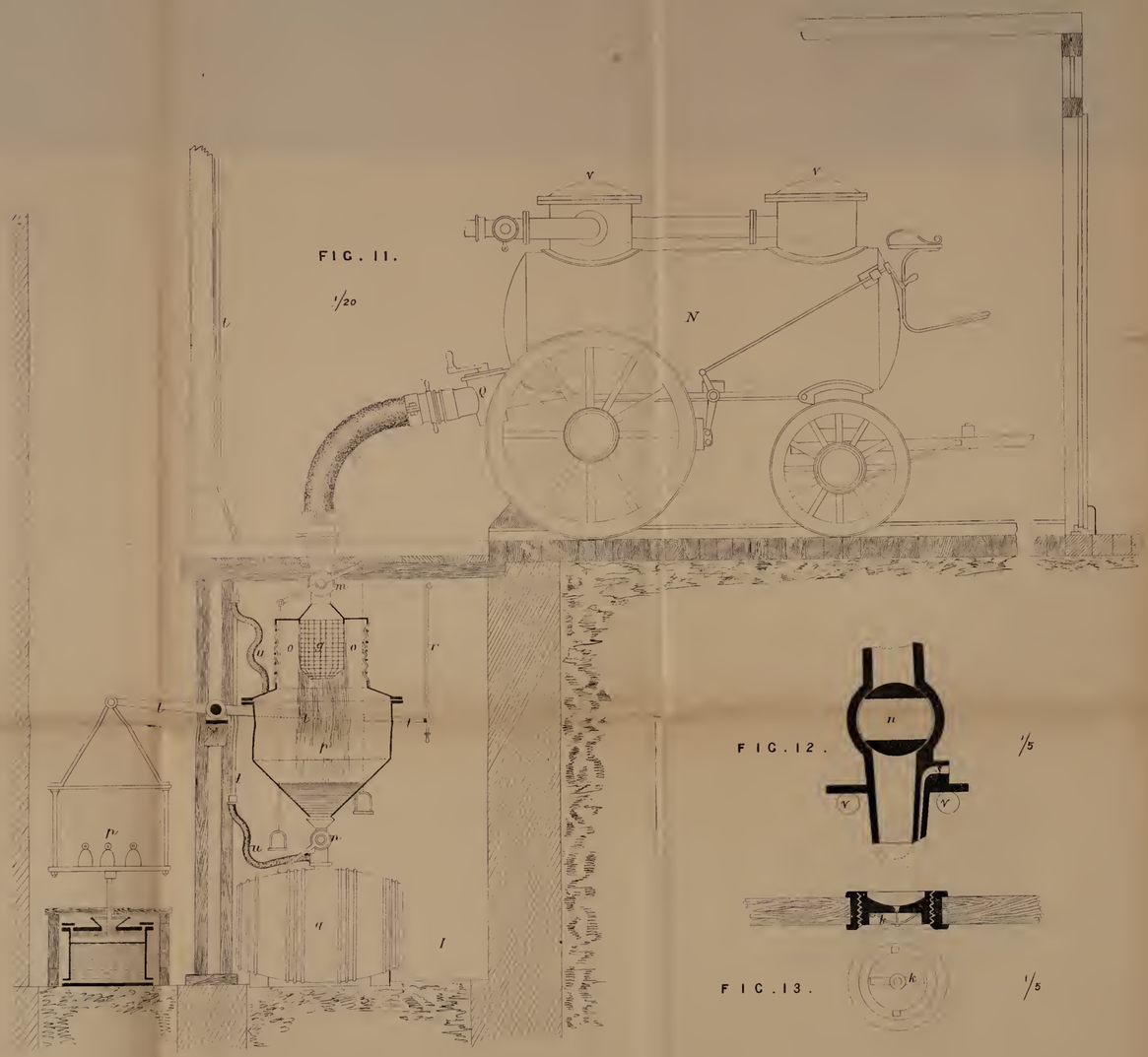
FIG. 8.

Drawn on Stone by Melby & Sons

LONDON: Printed by GEORGE EDWARD EYRE and WILLIAM SPOTTISWOODE,
Printers to the Queen's most Excellent Majesty 1869.

FIG. 11.

1/20



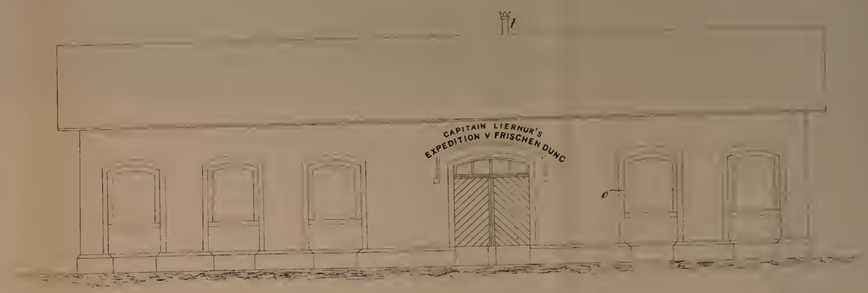


FIG. 10. 1/100

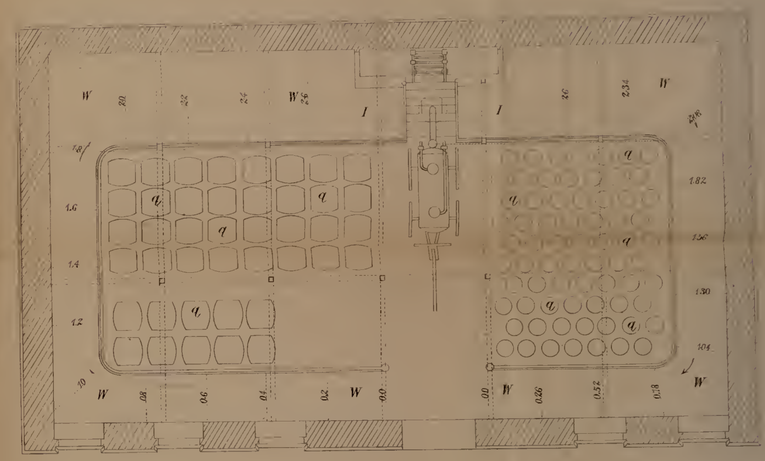


FIG. 12. 1/5

FIG. 13. 1/5

FIG. 14. 1/20

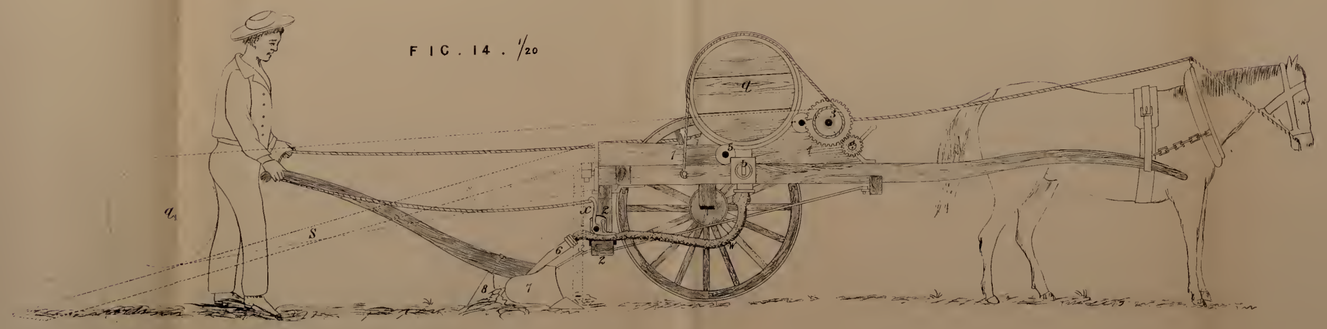
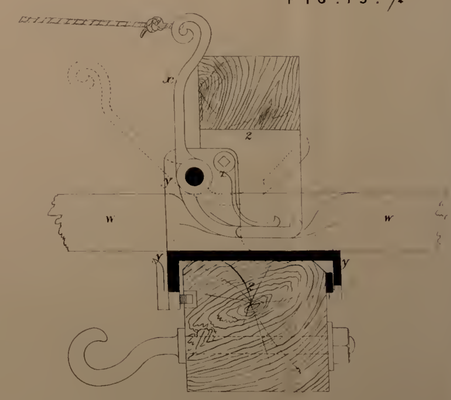


FIG. 15. 1/4



Drawn on Stone by Malby & Sons

London: Printed by George Edward Eyre and William Spottiswoode,
Printers to the Queen's most Excellent Majesty. 1869.